PROCEEDINGS

OF THE

ENGINEERS' CLUB

OF

PHILADELPHIA.

ORGANIZED, 1877. INCORPORATED, 1892.

VOL. XIII.

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Proceedings of the Engineers' Club of Philadelphia, Vol. XIII, No. 1, April, 1896.

A. Falkenau

Elected President, January 18, 1896,

for the Nineteenth Year of the Club, A. D. 1896.

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ANNUAL ADDRESS

OF

GEORGE S. WEBSTER, President.

Philadelphia, January 18, 1896.

GENTLEMEN:—I congratulate you upon the successful termination of another year of the Club's history, upon the continued and growing interest taken in all subjects pertaining to engineering advancement; also upon the number of valuable papers presented for discussion. The field of engineering has within the life of this Club developed so rapidly, and the number of large projects has become so great, that I have found it impracticable to attempt a faithful review in my annual address; even were I to attempt it, the result would be to a large extent statistical and prove uninteresting. My purpose is therefore to mention a few works of magnitude in our own country, particularly those in the vicinity of Philadelphia, to show the tendency of our profession towards still larger undertakings, and the greater importance of maintaining our local and national societies.

The *Railway Age*, in publishing records of railway construction

in the United States for the past year, gives 1,782.39 miles for 163 lines in 34 States and Territories. The small mileage is no doubt due not only to adverse conditions owing to business depression, but also to the great development and popularity of electric railways for the convenience of local passenger travel. Although the extensions have been small, nevertheless there have been great improvements made on the trunk lines in the construction of road beds, the replacing of old rails by new steel rails 60 feet long, weighing 100 pounds per yard, and the renewing and strengthening of bridges for the carrying of heavier loads and the increased speed of trains.

The Pennsylvania Railroad Company is about to commence some extensive changes in its alignment between Conemaugh and Ninevah, by which the distance along the bank of the Conemaugh River will be shortened 0.6 of a mile and curvature lessened 43 degrees, and also the straightening of the line at Radebaugh, involving the construction of a tunnel 2,100 feet in length. By this new line 233 degrees of curvature will be saved and a reduction made of 0.2 of a mile in distance. The change of line between Lilly and Portage saves 1.11 miles in distance, and 440 degrees in curvature. The new line, as projected, crosses the present line at six different points. There is practically a new line from Kinzers to a point west of Gordonville, on the Philadelphia Division, and also west of Rheems Station. The former line will eliminate 146 degrees of curvature and 0.32 of a mile in distance. Whilst the change at Rheems will save little in distance or curvature, it will reduce the maximum curvature from 5 degrees to 2 degrees. It is also contemplated to build two additional tracks on the north side of the Buffalo Creek Bridge, near Newport, on the Middle Division. This structure is now a five-span stone arch bridge, 186 feet 6 inches in length, 23 feet wide. The additional portion would be of the same length, and would increase the width to 38 feet.

Within the latter part of 1895 great attention has been given to the increase of speed for long distances on the trunk lines, not only in this country, but also in England. This is due to the rapid progress of the times and the demand for quick transit. The best recorded runs are as follows:

Fast run from New York to Buffalo September 11th, made over the New York Central Railroad; entire run 436.5 miles, having been made in 412 minutes, or at the rate of 63.57 miles per hour throughout, including two stops occupying four minutes. The train was made up of four cars and weighed 361,000 pounds. Including engine and tender, the train was 337 feet long, and weighed 565,000 pounds. Also, on September 25th, the 148 miles from Albany to Syracuse were covered in 130 minutes, or at the rate of 68.2 miles per hour. A train on the London and Northwestern Railroad made a run from London to Aberdeen, on August 22d, over a distance of 540 miles, in 512 minutes, or at the rate of 63.27 miles per hour, including stops. A fast run was made on the Lake Shore and Michigan Southern Railroad on October 24th, in which a portion of the route, a distance of 86 miles, was run at the average speed of 72.91 miles per hour. A still faster run was made on the Philadelphia and Reading Railroad on May 21st, from Camden to Atlantic City, a distance of 58.3 miles, in 46½ minutes, rate 76.5 miles per hour.

No better illustration of the progress and improvement in high-speed locomotive construction can be given than a brief statement of the work accomplished in this city at the Baldwin Locomotive Works, where 401 locomotives were constructed during 1895, and among this number the following may be noted as worthy of special consideration, representing new types or peculiarities of construction made necessary by the service to which the locomotives were adapted.

A fast passenger locomotive, built for the Philadelphia and Reading Railroad Company, is a new type comprising the Vauclain compound cylinders and a single pair of drivers, with a four-wheeled leading swing truck and a single pair of trailing wheels. These trailing wheels were mounted on an axle in the rear of the driving wheels, and their boxes held rigidly in the main frame. These wheels, however, have ¼ inch extra play on the track. The driving wheels of this locomotive are 84¼ inches in diameter. The dimensions of the cylinders are high pressure 13 inches diameter, low pressure, 22 inches diameter, with a stroke of 26 inches. The truck wheels are 36 inches, and the trailing wheels 54¼ inches in diameter. A 56-inch straight boiler is used,

adapted to carry a working pressure of 200 pounds per square inch.

A locomotive, designed for fast passenger service, was constructed for the Chicago, Burlington and Quincy Railroad Company, on the general lines of what is known as the Columbia type, having single expansion cylinders 19 inches in diameter by 26 inches stroke. The driving wheels are four in number and 84¼ inches in diameter. It was provided with a leading two-wheeled radius bar truck, the wheels of which are 50¼ inches in diameter, and two trailing wheels of the same size. The boiler is 58¾ inches in diameter, carrying a working pressure of 200 pounds. The design of this locomotive embodied some peculiarities of construction made to suit the road for which it was ordered.

During the year an order for heavy freight locomotives has been filled for the Government Railway of Russia, having compound cylinders, five pairs of coupled driving wheels and a single pair of leading truck wheels. These locomotives embodied Russian peculiarities, among which was their adaption to the use of naphtha as fuel. They weighed in working order about 84 tons, exclusive of the tender.

Among the novelties for the past year may be noted a special service locomotive for the San Domingo Improvement Company. The requirements in this case were that the locomotive must haul 50 tons up a grade of 475.2 feet per mile, and in order to accomplish this, a rack rail had already been introduced on the heavy grade; but as the use of this heavy grade would only be required during the construction of the road, it was desired that the machinery should be so arranged that the locomotive could be easily altered to operate only by ordinary adhesion. In order to meet these requirements, two separate and distinct sets of machinery were combined, one having double-compound cylinders to drive the traction wheels on the ordinary rails, and the other having two single expansion cylinders, arranged to drive the gear shaft in connection with the rack rail, each device being provided with its own throttle, reversing and valve gear, each one being entirely separate from the other, so that either or both could be used; in case the rack rail should be done away with, a pair of ordinary drivers could be made to take the place of the rack

wheels and be coupled to those already on the locomotive, and the other parts of the mechanism removed.

Great extensions have been made in electrical transportation within the past few years. The putting in operation in July last of an electric locomotive for hauling trains through the Baltimore Belt Line Tunnels, is the first instance of direct displacement of steam by electricity. On Octobor 6th, this electric locomotive is said to have pulled a train of 44 loaded cars and three steam locomotives, the total weight of the train being nearly 1,900 tons.

Electric traction is also being successfully operated on steam railroads in the cases of the Mount Holly Branch of the Pennsylvania Railroad, and the Nantasket Beach Branch of the New Haven Railroad. Upon this latter road a speed of 80 miles per hour is claimed to have been made in June last.

Street railway statistics for July, 1895, give 10,363 miles of electric railways in the United States, 1,914 miles operated by horses, 632 miles by cable and 679 miles by miscellaneous methods.

Dr. Louis Duncan, President of the American Institute of Electrical Engineers, in a paper on the substitution of electricity for steam on railways, read at the Niagara Falls meeting, makes the following statement: "It seems to me that the present is a crisis in the history of railways. Up to the present the steam roads have ignored the competition of electric roads or they have fought them. To-day they cannot afford to do either. In a few years electric roads will have absorbed all of the local traffic and will begin to cut into their transportation. The steam roads cannot afford this, and their only safety is to make of electricity an ally instead of an enemy, and this before it is too late. The tendency of passenger transportation on the steam lines has been in the direction of the greatest electrical economy, while the tendency of freight transportation has been in the direction of the least electrical economy."

How to meet this competition is a serious problem now being carefully studied by a number of steam railways. The electric lines are preferred because they give a cheaper and more convenient service at shorter intervals of time than could possibly

be afforded by a first-class steam railway with its heavy trains, expensive roadway, stations and line of equipment, and the comparative excessive cost of operation. These are conditions which the steam lines cannot ignore. The eventual outcome may be a division of the traffic, the steam railways taking the long distance passenger travel and heavy freight, and the electric railways taking the local passenger travel and light freight.

This tendency to use heavy locomotives and trains running at high speed on the steam roads, and the use of electric cars on public highways running at high speed, has greatly increased the danger of grade crossings, particularly in suburban sections, a matter which has been receiving attention in some of the large cities within the past few years, but now must be extended to the smaller towns.

The Pennsylvania Railroad Company has expended large sums of money in changing the elevations of its roadway so as to avoid grade crossings in Jersey City, Elizabeth, Newark, Trenton, Philadelphia and Harrisburg. There are at the present time active movements on foot for the abolishment of grade crossings in Chicago, Washington, Boston, Buffalo, Columbus, Cincinnati, Cleveland, and a number of other cities of importance.

The city of Philadelphia, owing to its great mileage of streets, has probably had carried on within its limits the greatest and most costly works of this character. Within the past decade the railroad companies and the city, separately and jointly, have constructed upwards of 135 bridges, and the city of Philadelphia has within the past year joined with the railroad company in an important improvement at North Penn Junction, by which the grade crossing of two great steam roads was abolished, and also that of five important public highways. This work was carried on under the charge of the city, it bearing two-thirds of the expense and the Pennsylvania Railroad Company bearing the remainder.

Councils have appropriated $6,000,000, to be expended under the Department of Public Works, for the construction of a subway and tunnel through the heart of the city of Philadelphia for the abolishment of grade crossings on the line of the Philadelphia and Reading Railroad Company's Main Line. This work contemplates

the construction of a large four-track tunnel, 3,000 feet long, and an open subway about 8,000 feet long, by which means 17 grade crossings on important thoroughfares will be abolished. The operation of lowering the railroad tracks and of depressing the freight and engine yards some 25 feet in the heart of a great city, involves many difficulties in its execution; among these may be mentioned the drainage, underpinning of existing buildings, making connections with industrial establishments and problems of ventilation.

In order to procure rapid transit through the city of Boston, work has been commenced in the construction of a subway through the most populous portion of that city. The work has been inaugurated and a considerable sum of money expended. It is intended to push this work rapidly to completion during the coming season.

In New York City the Commission appointed has recommended the construction of a road under Broadway and other streets at a cost, approximately, of $50,000,000.

Transmission of Power.

The construction of the Niagara Tunnel and the project to generate electricity by water power, and transmit the same for use in other cities, is about to be undertaken on a large scale by the Niagara Falls Power Company. It is reported that this company is to be prepared to furnish 10,000 horse-power to city consumers in Buffalo, June 1, 1897, and has obtained a grant from that city for that purpose, which grant will be for thirty-six years from the date of acceptance, and at the end of eighteen years the various conditions imposed by the franchise are to be subject to revision by a Board of Arbitration, consisting of a representative of the Company, the Mayor of Buffalo, and a third person to be chosen by these two. The grant provides against all possible damage to the property of Buffalo and its citizens, including the corrosion of pipes by electrolysis. An important provision is that no change of price for power shall be made after once being fixed.

It is interesting to note that among the uses to which the Niagara Falls electric power is first put, are the three comparatively

new industries,—the manufacture of aluminium, of carborundum, and of calcic carbide, the last-named for making acetylene gas.

It is also suggested to use the power which may be generated at the lower terminus of the Chicago Drainage Canal at Lockport, where there is a fall of nearly 75 feet to the level of Lake Joliet. An article in the *Engineering News*, states that a simple calculation shows that if the ultimate drainage canal flow of 600,000 cubic feet per minute were all utilized, over 60,000 horsepower could be developed by the erection of suitable works, and a good market could be found for it in Chicago, as the distance is small enough to make electrical transmission perfectly feasible.

An electrical power plant to supply electricity at Salt Lake City is being brought to completion by the Big Cottonwood Power Company. The power plant is located on Big Cottonwood Creek, about 14 miles from the city, where a fall of about 380 feet will be utilized to drive four 60-inch special double-nozzle Pelton wheels, each with a capacity of 620 horse-power net, at a speed of 300 revolutions per minute; each wheel will be directly connected with a 450 kw. three-phase general electric generator. A small storage reservoir, formed by an earth dam, has been built above the power station. A step-up transformer at the power station raises the voltage from 500 to 10,000, and a second transformer at the city reduces the latter to 2,000 volts. It is believed that the difficulties of transmitting electrical current for use at distant points are being overcome, so that in the future we may look to the transmission of great power to distant points for utilization.

Great advantage has been found in the substitution of electric motors for local steam engines and shafting in such places as rolling mills, dock yards, machine shops, etc.

Ship Building.

The product of American ship building during the last year has been a convincing demonstration to the capacity of America to efficiently build ships of whatever style and type, either mercantile or naval, which any nation may require.

In our great ship yards on the Delaware River, in this city,

rapid-firing guns of the Driggs-Schroeder type, varying in caliber from 1 inch to 4 inches.

The occasion of the opening of the Baltic Canal brought together the most powerful fleet ever gathered anywhere at any time. Eight nations were represented by 51 war ships, with the best and latest model of each class. The "Sardegna," belonging to Italy, was the heaviest and fastest battleship of 13,860 tons, and 19 knots of speed. While the United States sent no ships of this class, she was well represented by the "Columbia," one of the three triple-screw cruisers of the world, and the fastest cruiser afloat, with a speed record of 22.8 knots, and holding the record for the fastest voyage by a war vessel across the Atlantic.

Bridges.

In bridge construction, long and heavy structures crossing wide rivers have become usual occurrences. Among the important structures completed within the past year I would cite the bridge over the Missouri River at Sioux City, consisting of two 470 feet draw spans and two 500 feet through spans, carrying a single track railroad, two 11 feet roadways and two 5 feet footwalks. The structure weighs about 8,000,000 pounds, and was erected complete in just two months from the time of raising the first iron, being probably as rapid a piece of erection as has been done in bridge construction.

The Louisville and Jeffersonville Bridge consists of 4,065 linear feet of single track approach on the Jeffersonville side, one 210 feet span, three 546 feet spans, two 339 feet through spans, and 2,600 linear feet of approach on the Louisville side. The total weight of the structure is 14,000,000 pounds; it is designed to carry a single track railroad and two 5 feet clear sidewalks. It was complete in every particular on April 30, 1895. One of the 546 feet spans of this structure was raised complete in just fifty-six working hours from the time the first piece of metal was run on to the falsework; another record in bridge construction which, it is believed, has never been excelled. Both of the above bridges were erected by the Phœnix Bridge Company.

A steel arch bridge is now under construction across the Niagara River by the Niagara Falls and Clifton Suspension Bridge

Company. This arch is to have a span of 840 feet, and will be the greatest span steel arch bridge ever erected. The width of the bridge will be 49 feet and the total distance from cliff to cliff 1,268 feet, and it is estimated that it will require 4,000,000 pounds of steel to construct it.

The double-track railroad bridge now being completed across the Delaware River on the line of the Pennsylvania and New Jersey Railroad in this city is the most important railway structure in this section of the country. It consists of three fixed spans 533 feet long and one draw span 330 feet long, giving, when opened, a clearance on either side of the center pier of about 125 feet for navigation. The gross weight of the material in each of the fixed spans is about 4,200,000 pounds, and the estimated weight of metal in the draw span is 1,500,000 pounds. In general the material used in the calculated section of the main trusses is medium steel. The floor system and all wind bracings as well as lattice bars, tie plates and similar details in the truss members are composed of soft steel. Steam power will be used for turning the draw span. There will be about 27,000 cubic yards of material, including masonry, concrete and timber, in the main supporting piers. The approaches to the bridge over the river on both the Pennsylvania and the New Jersey shores consist of plate girder construction for a considerable distance. It is the expectation of the railroad company to have the bridge completed ready for service in time for the Spring business.

The city of Philadelphia has recently completed the construction of a three-span Pratt truss steel highway bridge across the Schuylkill River at the Falls. This is an unusually heavy highway bridge, being designed for a double-decked structure, having a roadway of 40 feet on the lower deck and 60 feet on the upper deck; the total weight of the portion now erected being approximately 5,000,000 pounds.

In September last, what is perhaps the longest and heaviest plate girder ever constructed in the United States, being 122 feet 10½ inches long, 10 feet 6 inches depth over all, and weighing 50 tons, was transported from the Shiffler Bridge Works at Pittsburg, in one piece over the Pennsylvania and Reading Railroads, to the new bridge which is being erected at the intersection of

Sixth Street and Allegheny Avenue by the city of Philadelphia, and was there successfully placed in position.

High Buildings.

From the reports in engineering papers the record for rapid erection of tall steel buildings has been broken by the erection of 13½ stories of the iron work for the Fisher Building in Chicago in 14 days. Previous to this performance the erection of 9 stories of the Reliance Building in Chicago in two weeks was the best record. The Fisher Building is 18 stories or 235 feet high and covers a ground area 70 x 100 feet. 31 working days were occupied in erecting the whole framework, 18 stories, attic and roof. The construction of high office buildings with frameworks of iron and steel, carrying the exterior and interior walls and partitions, has become an established feature in nearly all large American cities. This style of construction originated in Chicago, in its practical application at least, and that city is reported to have at the present time more buildings of the steel skeleton type than all other American cities together. The use of rapidly moving passenger elevators has made the construction of high buildings profitable.

The question of proper materials for fire-proofing buildings of this kind and also for the best preservatives of the metal entering into their construction, is of vital importance to the engineer.

Waterways.

The Convention of the International Deep Waterway Association, held in Cleveland, Ohio, in September, resulted in attracting considerable public attention to deep waterway projects.

Owing to the great development of traffic on the Great Lakes the proposition to build a ship canal from them to the Atlantic Ocean, which had been talked of for several years, has recently developed new interest.

Probably as an outgrowth of this convention, the President of the United States appointed a Deep Waterway Commission, in accordance with an Act of Congress, ordering them to make inquiry into the feasibility of constructing a deep waterway, capable of admitting ocean steamers to the Great Lakes, and to report

upon the most convenient location of such a canal and its probable cost. This commission is to confer with a similar body appointed by Great Britain or Canada, and if any part of the said waterway be located outside of the United States, the report is to include information upon the necessary treaty arrangements which would make the canal free to both countries.

In this connection, mention may be made of the intention to utilize, together with the Illinois and Mississippi Rivers, the Chicago Main Drainage Canal of the Sanitary District of Chicago, which extends from the South Channel of the Chicago River southward to Lockport, as a free ship channel navigable for boats of 22 feet draft. The work of the district will constitute about two-thirds of the entire cost of the ship waterway from Chicago to the Mississippi River of as great a depth as that between St. Louis and New Orleans will be on the completion of the Government work upon the Mississippi.

The estimated cost of the work under contract is about $19,-000,000, and the total estimated cost of construction, both that under contract and that to be contracted for, including engineering and superintendence, in round numbers is $23,875,000. The estimated cost of the completed canal, including right-of-way and all expenses, will be $27,303,216. This estimate is on a basis of fixed bridges across the canal. The cross-section of the Chicago Sanitary Canal is greater than that of either the Suez, the Manchester or North Sea Ship Canals.

There has been much controversy upon the effect which the Chicago Drainage Canal, when in full operation, will have upon the level of the Lakes. The Secretary of War has appointed a Board of Experts to report upon the subject.

An article in the *Engineering News* of October 3, 1895, states: "The engineering questions and legal questions which have grown and are likely to grow out of Chicago's great drainage ditch, are of absorbing interest, because to a large degree they are entirely unprecedented. Never before in the world's history has any work of man been carried out that affected the water line on four thousand miles of shore. The endless contentions and disputes to which riparian rights have in all times given rise are well known, but past history has never recorded a ques-

tion of riparian rights affecting so vast a territory and such a multitude of interests."

From the report of the Nicaragua Canal Commission recently published, it appears that the commissioners find that new and exhaustive surveys will be necessary before sufficent data will be at hand to make any conclusive estimates and reports upon the final location, and they give their own conclusions and estimates with this caution. The report practically condemns the present location from Greytown to Brito, or at least suggests many marked departures from the plan proposed, and increases the cost of the canal from the company's estimate of $69,893,660, to a provisional estimate of $133,472,893. To obtain the necessary data for the finding of a final project, the commission says that eighteen months will be required, covering two dry seasons, and that this investigation will cost about $250,000.

As showing a renewal of interest in canal projects, the State of New York has appropriated $9,000,000 for improving the State canals. Among the improvements contemplated is the deepening of the Erie and Oswego Canal to 9 feet, except over aqueducts, miter sills and other permanent structures, where the depth is to be at least 8 feet.

The Champlain Canal is to be deepened to 7 feet.

There is also a project under consideration to construct a canal from Pittsburg to Lake Erie, with the view of giving another outlet from the coal fields of Pennsylvania to the Great Lakes, and also to facilitate the transportation of the Lake Superior iron ore to the furnace districts of Western Pennsylvania.

The city of Philadelphia, situated as it is at the junction of two large rivers, upon which it has an available frontage for shipping purposes of 33 miles, has a waterway to the sea which is capable of being made available for the largest ocean vessels. The United States Government is expending large sums of money for the purpose of deepening and rectifying the channel. The total cost, estimated by the Board of Engineers of 1888, for the dredging of the harbor between Philadelphia and Camden, was $3,500,000. Of this, $1,617,340 was expended up to the end of the last fiscal year.

During the past year the city of Philadelphia, under an appro-

priation of Councils for the purpose of improving the waterways of the port of Philadelphia, has been co-operating with the United States Government in improving the channels of both the Delaware and the Schuylkill Rivers, a contract amounting to $175,000 having been entered into for the removal of the ledge rock and other deposit along the Schooner Ledge Range in the Delaware River immediately south of the city, and another contract of $40,000 is being prosecuted in the deepening of the Schuylkill River from its mouth northward. All of the above work is being carried on according to plans of the United States Government by the Department of Public Works of Philadelphia.

The construction of deep canals, and the extensive dredging of existing waterways, have led to the invention and use of large and powerful steam shovels and dredges. One instance might be quoted in connection with the work now being carried on in the Delaware River: a large hydraulic dredge, "The Delaware," engaged in removing the material from the channel and depositing it on Petty's Island, on October 9, 1895, handled during twenty-one working hours 10,994 cubic yards, as measured in excavation, or 13,743 cubic yards measured in scows, representing an exceptionally large day's work.

The works of great magnitude, importance and cost, which are now in course of construction, and which are contemplated in the near future, clearly show the great strides that have been made in the engineering profession in the past few years, and also indicate the great responsibilities resting upon the engineer of this day. The centralization of population, as shown by the great growth of our cities, the competition in business, the demands of transportation and the vast powers now under the control of man, make it necessary for the engineer to design heavier constructions and machinery of greater strength; also to proportion all the parts that each shall perform full duty, thus emphasizing the necessity of a higher education and a full knowledge of the properties, both chemical and physical, of all materials used.

This knowledge can only be properly attained by a systematic engineering inspection, a matter of vital importance to every engineer, when it is considered what a failure amounts to in a modern construction of magnitude. The engineer can no longer

afford to isolate himself from his brothers in the profession, but must constantly keep in touch with what others are doing and comparing works and results.

In order that intelligent comparisons may be made, it is absolutely necessary to establish uniform methods for determining the strength and other properties of materials and the efficiency of mechanical work. Some especially interesting work is being done in this line of experimental engineering, and the wide field which this class of work is embracing, is one of the noteworthy developments of recent years.

Mr. Theodore Cooper has well remarked, in discussing American Railroad Bridges: " The investigation made during the building of the St. Louis bridge into the strength and other properties of materials of construction, and especially the testing of full-size members and their detail connections, not only advanced very much our knowledge of these matters, but also gave impulse to such investigations, which has continued to the present."

The construction of numerous important bridges and buildings in which a regular system of inspection has been adopted, including tests of full-sized members, has given a further impetus to this work. The long series of tests made by the United States Government at Watertown, numbering probably more than 30,000 in all, constitutes a mine of most valuable information covering numerous tests of full-sized members both in tension and compression, of riveted joints, of timber, of brick, of stone, etc.

It may be noted in this connection that the Watertown report includes an interesting series of tests of brick piers, made under the auspices of the Building Commissioners of our City Hall.

The work which is being done in this field at the present time by the American Society of Mechanical Engineers has given highest credit to that society. Both the American Society of Civil Engineers and the Institute of Mining Engineers are also doing valuable work in this line.

Many of our larger institutions of learning, recognizing the importance of graduating engineers fully equipped in this branch of the profession, have established physical laboratories as necessary adjuncts to their technical schools.

Although rapid progress has been made in this branch of en-

gineering, yet the engineer is compelled to acknowledge that there are still new and wide fields for investigation.

The extensive construction of iron and steel structures, some of the principal members of which are necessarily so enclosed as to be inaccessible, emphasizes the importance of a fuller knowledge of proper preservatives. Municipal engineers are in search of information as to the effect of electrical currents, carried in recently laid conduits, upon the water and gas supply pipes.

More complete data is also desired to determine the proper composition and quality of material entering into all classes of municipal work. It is important that our large cities should establish fully equipped chemical and physical laboratories in connection with their engineering bureaus. The first cost or outlay would be but trifling, compared with the advantages to be gained.

A great mass of data is accumulating year by year in both public and private laboratories, increasing our knowledge of the properties and uses of materials, of power plants, and of electricity. Yearly this makes it necessary to revise specifications, and yearly we are better able to define, by systematic testing, the grades of material desired and the standards of efficiency required for all classes of mechanical work, and therefore we are enabled to construct more intelligently and economically.

The field of engineering has within the past few years assumed such vast proportions that the individual engineer has necessarily become a specialist, yet he is frequently called upon to design and execute works of magnitude which require special knowledge in a number of branches, and in order to utilize to advantage the rapidly accumulating information which is at hand, he must have a full knowledge of the conditions under which this information was obtained. The engineering society affords that opportunity and opens the door to a free interchange of ideas and experience.

The presentation of original and descriptive papers upon engineering subjects and the full and thorough discussion which generally follows, develops interesting facts and indicates the latest and best practice, and these are the means of constantly keeping the profession acquainted with the progress and discoveries that are being made in every field.

The recognition of a higher standing in the community of the professional services of the engineer must come largely through the medium of our local and national societies.

In closing, I desire to acknowledge the kind support given me by the Board of Directors and the individual members in my administration of the office of President.

II.

DISTRIBUTION OF ELECTRICAL ENERGY FROM A CENTRAL STATION.

By WILLIAM C. L. EGLIN, Active Member of the Club.

Read January 4, 1896.

IN considering the subject of the distribution of electrical energy from a central station, it is my intention to speak more in detail of the distribution of electrical energy in large cities using underground conductors, with a continuous supply—twenty-four hours per day, and seven days per week. The energy is to be supplied in such a form as to meet all the commercially practical uses to which electrical energy may be put, such as for motors of any size, incandescent lamps, arc lamps, the various heating devices, telegraph instruments, etc.

Each lamp or motor is to be independent in its operation and all appliances are to be free from danger to life due to touching the wires carrying the current. Many engineers are inclined to think lightly of the personal danger from a shock in connection with the distribution of electricity, but I feel that those persons have not been called before a coroner's jury, or had a serious shock themselves. Few of us have a proper respect for the "juice" until we get a sample of the medicine.

The object of all the different methods in use to distribute electrical energy, is to reduce the amount of current flow and increase the pressure, and to have a uniform pressure at the consumer's, which is independent of the load; the only exception is the series system in which the flow of current must be kept constant. The reason for this is that for a given amount of energy to be transmitted from one point to another, the loss in watts, which is the amount of pressure used to overcome the resistance of the conductor and expressed as the difference of potential between the ends of the conductor, multiplied by the current—shall be as small as possible.

Silver and copper have the lowest electrical resistance, being very nearly the same. The price of silver prohibits is use. Iron

and steel have from six to seven times the resistance of copper, so that, should these metals be used, the wires would be required to have a cross-section six to seven times that for copper. This would add to the cost, and difficulties of construction, in many ways which are easily apparent, so that practically, copper is the standard conductor.

The carrying capacity of a conductor depends on its resistance and the surface exposed to radiation. As it is known that each increase of current in a conductor increases its temperature, due to the amount of energy expended in overcoming the resistance of the conductor, the carrying capacity is limited by the safe allowable increase in temperature. This necessitates increasing the cross-section of the conductor for large currents so as to reduce its resistance.

The distribution of electricity from a central station may be divided into two general classes; systems in which an alternating current is used, and systems in which a continuous or direct current is used. These may again be subdivided into low tension systems and high tension systems.

Each of these has its peculiar advantages which I will describe in brief, as it is important to have some general knowledge of the methods in practical operation before considering a particular case.

The advantage of an alternating current is that by the use of extremely simple apparatus, free from any moving parts, the energy may be transformed from a high to a low pressure or *vice versa*, so that by its use a given amount of energy may be transmitted from one point to another at a high pressure, and small volume, the pressure being then reduced at the consumer's point to any required amount, the volume being increased in proportion to the reduction in pressure.

The apparatus required in this case is an alternating current generator and usually a relatively small continuous current generator, to magnetize the field magnets of the alternator. When the units are large they are generally designed to generate the current at a low pressure to prevent danger to attendants and to assist in the insulation qualities of the machine. A step-up transformer is then used to raise the potential or pressure to about

2,000 volts. From this point a number of circuits are run, each circuit being entirely independent. These circuits might be called the street mains, and when a service connection is desired at any point, these wires are tapped and again connected to a transformer, which reduces the pressure to 50 or 100 volts, as the case may require. It it sometimes advantageous to use one transformer for a group of consumers close together and so save the expense of a number of small transformers.

The losses in this method are in the step-up transformer, the line wire and the consumer's transformer. When there is a large number of consumers, the cost of the transformers with the consequent increase in repairs, renewals, etc., becomes an important factor and detracts very much from the other advantages of that system.

The principal advantage is in a case in which the distances between the consumers and the station is great, as the loss in line wire may then be reduced to a minimum, controlled only by the practical limits of the pressure. Should alternating currents be used without transformers, the operation would be similar to the description to be given for direct current distribution.

High tension direct currents may also be used in the distribution and then converted to low tension at the point of supply by means of a rotary transformer. A rotary transformer is a motor-driven dynamo, designed to work when directly connected to the high tension mains. This transformer would require regular attention and could only be used in sub-stations, or in some special cases for a small number of consumers each requiring a large amount of energy.

Storage batteries could also be used for this purpose, in which case the batteries would be charged in series and discharged in multiple or in groups.

The high tension system which is in most general use, is the one in which the lamps are connected in series, that is, the whole volume of current passes through each lamp or other apparatus in succession. The energy used in each depends on the amount of current flowing, multiplied by the difference of pressure between the points of entering and leaving the lamp or motor, the total difference of pressure generated varying with the load.

The rock on which this system fails, as far as incandescent lighting is concerned, is the fact that, should the circuit be open at any point, the current is shut off from all the lamps in that circuit. This can often be avoided by placing in each lamp an automatic cutout or short-circuiting device, which, in the event of such a failure of the lamp as will interrupt the current, will again complete the circuit, and thereby again supply the other lamps in that circuit with current.

With small units, such as incandescent lamps, this would add largely to the complication and to the possible failure of the system; it has, in fact, been abandoned in practice. For large units, arc lamps, etc., the cutouts do not require to be so sensitive. The number of units being very much reduced, the failures are much fewer. Allowing even a perfect cutout, which protects only the lamps, all the conductors leading from one lamp to the other must still be kept in perfect order.

This system is, however, extensively used for arc lighting, being extremely simple, and its first cost is very low; it was the only system in use before the invention of the high resistance lamp by Mr. Edison. The incandescent lamps used in the series system were made to operate with a low pressure from 10 to 20 volts, and a current strength of 4 to 5 amperes, so that a greater number might be used on any circuit.

With the invention of the high resistance lamp, Mr. Edison also gave us the method of connecting the lamps, known as the multiple arc or parallel system, that is: each lamp has a direct connection to the generator through the main conductor, so that for each additional lamp there is a proportional increase in the current sent over the conductors.

Before considering low-tension systems of distribution let us look at the conditions which limit the pressure when the energy is to be used for incandescent lighting. The limit of pressure of a 16 c. p. lamp is about 115 volts, which is due to the difficulty of making a carbon filament thin enough to give 16 candles and be stable at higher pressures.

220-volt lamps are now being made with an efficiency of about 3.6 watts per candle, which is about 20 to 30 per cent. lower in efficiency than a 115-volt lamp, and could be used economically

in some cases, on account of the reduction of current required. At present, however, they are not used extensively enough to form a proper opinion of their qualities, and it may be necessary to use special fittings when 220-volt lamps are used on a three-wire system, with 440 volts between the outside conductors.

As the efficiency of an incandescent lamp depends on the temperature to which the carbon is heated, the higher the temperature the greater the light per unit of energy. For this reason it is desirable to burn the lamp at as high a temperature as possible. In practice, the temperature is limited by the fact that carbon is fusible, and before it fuses the carbon softens, small particles detaching themselves and flying to the glass globe, blackening it and obscuring the light. To secure an economical lamp it must be operated near this fusing point. This necessitates a uniform pressure, as an increase in pressure would bring the carbon up to the fusing point or nearly so, causing the lamp to blacken and fail with a short life.

When a uniform pressure cannot be obtained, then a less efficient lamp should be used, the temperature of the filament of which would be lower, leaving a greater margin between the temperature at the normal candle-power and the fusing point of the carbon. The life of a lamp depends on its efficiency; the lower the efficiency the longer the life; the higher the efficiency the shorter the life. Lamps are usually made to give one candle-power for 3 to 4 watts.

There is another characteristic of all incandescent lamps which has an important bearing on the distribution, that is, the very rapid decrease in candle-power for a slight decrease in pressure. This is shown in the curve, Fig. 1, in which the candle-power of a standard 16 c. p. lamp at 110 volts is plotted for a rise and a drop of 10 volts in the pressure. This shows very clearly the small variation in pressure allowable at the lamp, in order to give a uniform light.

The multiple arc or parallel system of distribution at first fulfilled all the requirements, as the number of lamps was small and the distances were short, and it is to-day extensively used in isolated plants, supplying lights in one building. When the distance between the lamps becomes greater than a few hundred

feet, the conductors must be very large in order to reduce the drop in pressure caused by their resistance.

As an example of this I have arranged twelve lamps of 11 candle-power, with a resistance in the conductors equal to that of 200 feet of No. 14 B & S copper wire between each two

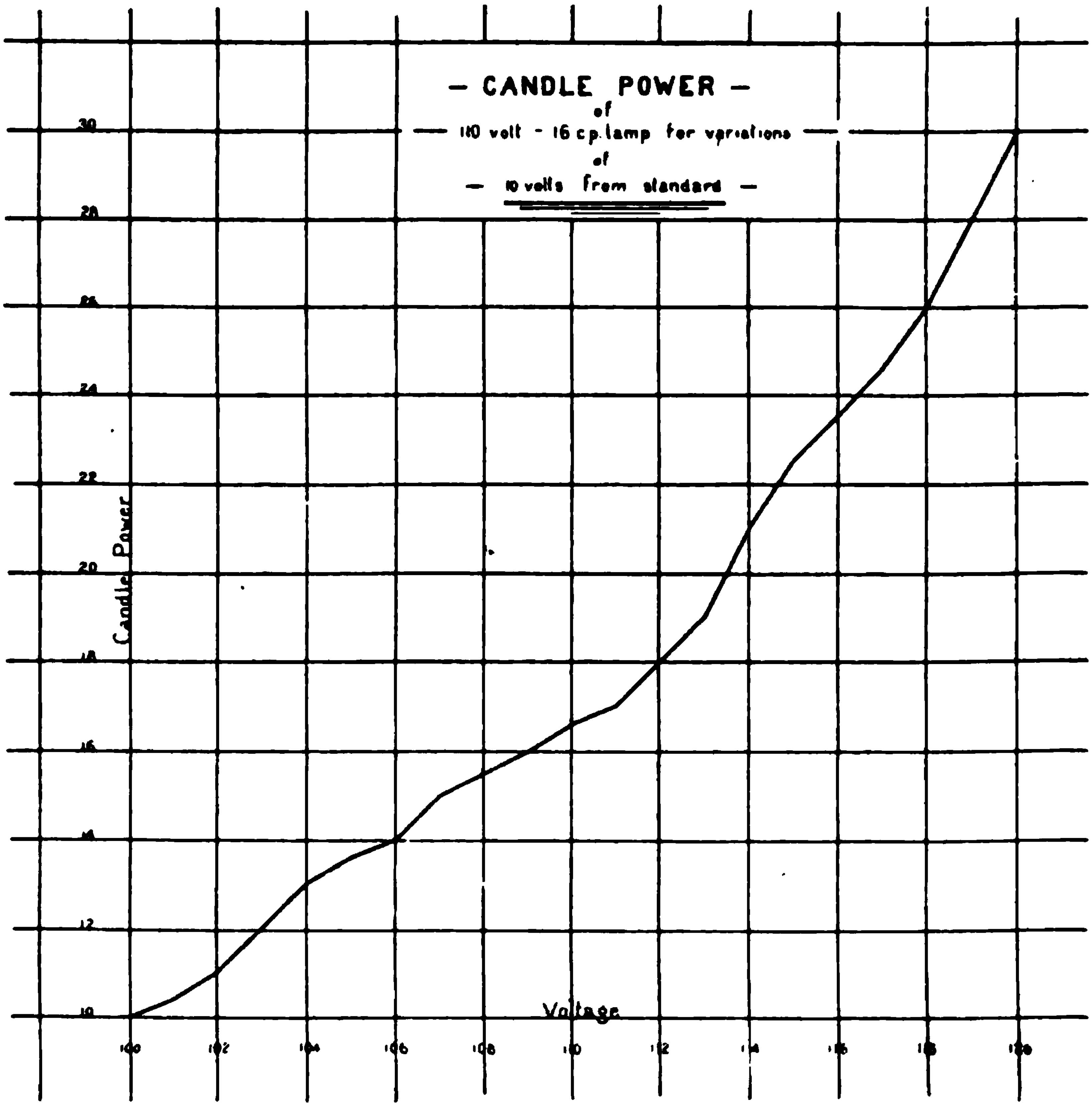


Fig. 1.

lamps, or a total length of 2,400 feet. This size of wire is commonly used in houses to supply twelve lamps at a short distance from the main. These lamps have been carefully selected, and each at its normal pressure of 114 volts gives 11 candle-power. When all are lighted as arranged, the light from the last lamp is equal to only 1 candle-power, which shows very clearly

the limitations of this method of distribution as far as the central station is concerned. Calculations of the size of wire necessary to supply ten city squares with 800 lamps of 16 candle-power per square—the average distance per square being 500 feet—show that each conductor at the station end would require to be 7½ inches in diameter. This is computed on a 3 per cent. loss.

The next step to be taken was the arrangement of the conductors on the principle of the Edison 3-wire system. This system is somewhat similar to a series multiple arrangement of lamps, in which two lamps are connected in series, and these pairs of lamps in multiple, with the addition of a third wire from the station, which is connected between the lamps in series; the object of the third wire being to supply the uneven balance of lamps and make each lamp independent. By this means the

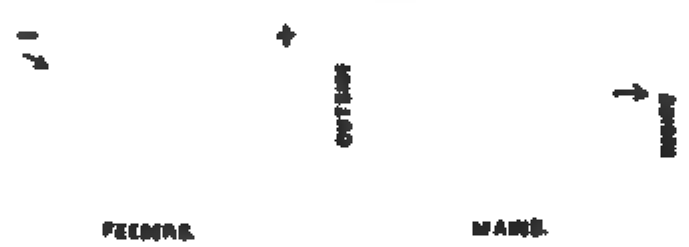


Fig. 2.

current is only one half, so that we can double the distance. But even this arrangement would be impracticable for supplying current on a large scale from a central station.

The next and most important improvement to be made in low-tension distribution was in the introduction of feeders. In this case the conductors are divided into two parts—the main or consumption circuit, to which all services are attached, and a feeder to supply that main, the feeder having no lamps connected to it between the station and the main (see Fig. 2). The length of the main is reduced to one square and is fed from both ends, thus making the length only one-half of a square.

The fall of pressure in the feeder has no effect on the lamps, as they are connected at the end of the feeder, the loss in the feeder being made up by an additional pressure at the station, so that now, instead of being limited by the fall in pressure, we are limited only by the carrying capacity of the feeder.

In supplying a large area, the mains are laid around each block, and are connected with coupling boxes, each 20 feet 6 inches apart, to which a service connection can be made, the ends of these mains being connected together through safety fuses in a junction box, placed at the intersection of main streets, and to these junction boxes are run the feeders.

Three small conductors are also placed with each feeder-tube, and connected with the junction box end. These wires are used to indicate in the station the pressure at the end of the feeder.

When the load is fairly uniformly distributed among the feeders, the pressure will be uniform at the ends, but in practice this is a condition which rarely exists, one section often being at its maximum load when another is at its minimum, so that it is necessary to have some means to vary the loss in the feeders. In Fig. 3, a characteristic curve of the load on a station is given, showing the great variations of the load during twenty-four hours in the winter months.

To meet this, equalizers were inserted in the conductors. This is an artificial resistance, which can be varied, thereby varying the resistance in the feeders and consequently the pressure at its ends.

Although by this means a uniform pressure was obtained, it was a step in the wrong direction, considerably reducing the economy of the feeders, and has been superseded by auxiliary "bus bars" in the station, having different pressures, all the feeders having nearly the same loss being connected to the bus bar which has the proper pressure for that loss.

There are in use a number of different methods to effect feeder regulation, which have to be used under special conditions. The district to be supplied, and the character of the load in the district must be carefully studied before deciding on the method of feeder-regulation. The most useful of these devices is a booster, which is a supplemental dynamo driven by a motor, and is connected in series between the bus and the feeders by means of the proper switchboard appliances. Its use is to increase or reduce the pressure on feeders, whose total load would not warrant the running of one pair of machines on a separate bus. The booster can also be made to regulate automatically the pressure at the

feeder ends either by means of a special winding or by the regulation of the motor-speed, or by hand regulation.

The advantages claimed for a booster are:

(1) It furnishes a convenient means of throwing at once an extra pressure upon any feeder receiving an extra load.

(2) It enables any feeder on a multi-pressure bus system to be

Fig. 3.

transferred from one bus to another without causing any flicker at the lamps.

(3) It allows of the tying together of the centers of distribution of several stations, so that the load of any station may be at once assumed by any one of the others.

(4) It does away with all feeder-equalizers, and other energy-consuming devices for obtaining equal distribution of pressure at the lamps.

(5) It allows of the economical and conservative development of new lighting territory.

(6) It enables current to be supplied economically from a lighting station, already well established in a business district, and operating at a high state of efficiency, to a resident district which would not warrant the outlay required for a sub-station.

There are three methods used in underground construction: a subway large enough to place the cable and for a man to work; conduits terminating in manholes at the intersection of streets; and wires buried in the ground.

A subway is possibly the ideal method of placing the conductors. The many practical objections in cities have prevented their use. A few of the objections are, the great first cost; danger of serious explosions from collection of sewer or illuminating gas; the alterations which it would be necessary to make in sewers, water and gas pipes and other underground construction, in order to secure the space required for the subway.

In conduit systems the principal material used for the conduits are wood (treated to prevent decay—usually creosoted), terra cotta and iron tubes, either laid in cement or cement lined. The most important consideration in a conduit is to select a material that is durable and free from projections or cutting edges which may injure the cable. The insulating qualities of a conduit are of little value, for in wet seasons more or less water is sure to find its way into the conduits. The conduits should be run in straight lines from manhole to manhole, and for this reason the ditch should be opened the entire length before any conduit is laid, to prevent complication due to material already in street, obstructing the way, especially at the intersections of streets.

The advantage of placing cables in conduits is that they may be inserted and withdrawn at any time, allowing a damaged cable to be removed and replaced without opening the street. The cables are drawn into the conduits by means of a rope attached to a windlass, which is first introduced by means of sectioned rods pushed through from manhole to manhole. It is customary to rod the conduit as soon as completed, leaving a pilot wire (No. 10 galvanized iron) remaining in the duct so as to insure that the conduit is free from obstructions.

After the cables are laid in the conduits, the various sections are joined together either by means of clamps or soldered joints, a box is placed around the joint and is filled with a compound.

When taps have to be made in a conduit, the street would require to be opened, or a connection taken from a manhole. As it is necessary to make provision for service connection on mains in front of each house, a conduit would be of little value except as a protection from mechanical injury to the cables, as a single service connection would prevent the cables being withdrawn. To meet this requirement the Edison tube system has been devised.

An Edison tube consists of three conductors contained in a wrought-iron pipe 20 feet long, and insulated from it, the con-

Fig. 4.

ductors extending about 3 inches beyond each end of the tube. The conductors are separated from one another by means of a spiral winding of prepared rope, and bound together to form a triangular bundle, which is pushed into the pipe. The latter is afterwards filled with an insulating compound (under pressure to prevent air bubbles), and the ends closed by means of hard rubber plugs.

As this system is a sectional one, each tube is a complete unit and is carefully tested before being shipped. A number of these tubes being joined together by means of flexible joints and a box clamped around them, which is filled with insulating compound as shown in Fig. 4, a line of any length may be made up in this manner, and by means of proper joints and elbow

Fig. 5.

Fig. 6.

Fig. 9.

before and after it is laid. A test should also be made after each joint is finished and no work should be passed that falls below the required standard of insulation. Careful testing is absolutely essential to successful operation of underground work, both during the construction and the operating periods.

Fig. 8 shows the interior of a manhole with the arrangement of the feeder cables and the main tube. The cover for this manhole had the form of a tub, the space on the top being filled with the same material that the street is paved with. This removes the objection which has been the cause of serious complaint, both from citizens and the city authorities, of noise and the danger to horses slipping on the large iron covers. Fig. 9 shows three manholes with this form of top and one with the old style.

DISCUSSION.

In the discussion which followed this paper, in answer to questions, Mr. Eglin stated that high resistance lamps had been successfully made to give 32 candle-power, with an electrical pressure of 220 volts, but that for smaller candle-power the filament for such high pressure would be too fine to be mechanically practicable. The alternating system of current distribution is the most economical for scattered business or great distances, but it has the great disadvantage of not being so safe to the consumer. The transformers sometimes fail and the high-pressure current then comes directly to him.

Regarding electric current meters, Mr. Eglin explained that in mechanical meters a clock-like device is necessary, and is subject to the inaccuracies of poor regulation. In chemical meters, on the contrary, defects in the condition of the meter plates or the solution generally result in showing a smaller consumption of current than that actually supplied. In a series of investigations in the latter class of meters, the only case where they read high was when the plates were very dirty, and in actual practice a 2 per cent. error is considered a very bad one. Excessive meter records are generally caused by leaks from the conductors.

Others taking part in the discussion cited cases where mechanical meters had been made to register excessively by insects or small animals moving over them; instances where storage batteries had been used as auxiliaries to central station distribution, were also cited.

III.

THE QUEEN LANE DIVISION OF THE WATER-WORKS OF PHILADELPHIA.

PART I.—THE BOILERS.

By John E. Codman, Active Member of the Club.

Read February 1, 1896.

The boiler power required for the Queen Lane Pumping Station can be stated in the following problem. Given 80,000,000 gallons of water per twenty-four hours, to raise 225 feet high; required the boiler power to do the work with economy of fuel and labor. It is not necessary, for the purpose of a computation of this kind, to enter into very minute or accurate calculation. The term Horse-Power can be applied to a boiler as a unit of measurement only by an equivalent. This unit of boiler power, or horse-power, is now generally accepted as that required for the evaporation of 30 pounds of water per hour from a temperature of 100 degrees Fahrenheit, into dry steam at 70 pounds gauge pressure, or, what amounts to the same thing, 34½ pounds of water per hour from and at 212 degrees Fahrenheit. A simple computation shows that to raise 1,000,000 gallons of water in twenty-four hours 100 feet high, will require the continuous expenditure of 17½ horse-power, to which must be added the friction in the pumping mains and pumps, which will approximate 2½ horse-power more, or say, for a boiler computation, 20 horse-power per million gallons, raised 100 feet. Applying this computation to the problem of raising 80,000,000 gallons of water 225 feet high in twenty-four hours, it is found that a continuous expenditure of 3,500 horse-power will be required.

Assuming the evaporation of 34½ pounds of water per hour as the equivalent of one boiler horse-power, 3,500 horse-power will require the evaporation of 120,750 pounds of water per hour. The 24 boilers designed for this work will each evaporate 5,000 pounds of water per hour into dry steam, with economy in fuel and labor; and can be forced to evaporate 8,000 pounds per hour with a fair degree of economy.

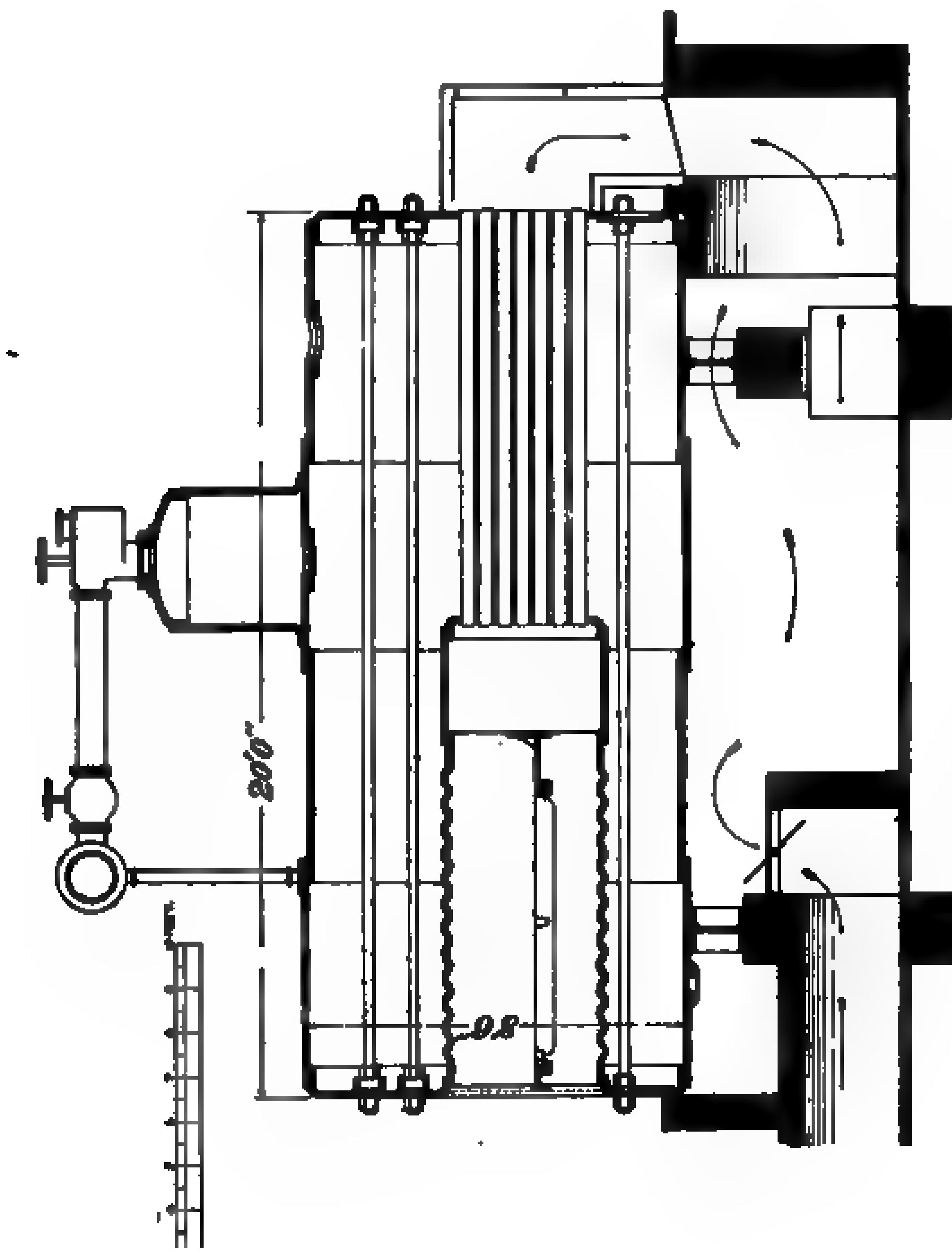


Fig. 1.—Elevation and Sections.

An ordinary high duty engine of the present day will not require more than 20 pounds of dry steam per horse-power per hour. To this amount must be added the steam required for donkey feed pumps, electric light plant and loss by condensation in the steam pipes between boiler and engine. These quantities can be very closely approximated, but the uncertain ones of leaking valves and pistons on the engine, scale, dust and ashes on the boiler tubes, and the occasional necessity of stopping one or more boilers for repairs, often occurring at times when the greatest demand is made upon the plant, make it a matter of the greatest importance that ample boiler power be provided. Especially is this so in a plant of this kind, in which the work is continuous.

I think it good engineering practice to provide ample boiler power, and, in the present case, an apparent excess of boiler power over the requirements of the engines. It will be found that this margin, when in actual operation, will be greatly reduced, and periods will occur when the demand for steam will require the forcing of the plant beyond the estimated capacity. When large volumes of steam are required at regular intervals of time, I think a boiler of this character is more suitable for the work than one with a smaller steam space. The large area of water surface, the facility given the steam to separate from the water, and the large steam space over the water, are factors in the formation of dry steam, and are among the most essential points in a steam generator.

Actual experiment and experience have shown that this form of boiler will furnish a better quality of steam than the ordinary form of marine boiler, known commonly as the *Scotch Boiler*.

In form, the boilers are much like the plain cylinder return tubular, and any ordinary boiler shop of the present day can construct them. The corrugated furnace flues are manufactured now in this country, although the first used in the Bureau were imported from England. With the exception of the corrugated flues there are no patented parts in their construction.

The boilers are 8 feet 6 inches in diameter and 20 feet long. Each has ninety 4-inch tubes, two Fox's corrugated flues, and twelve 2½-inch staybolts that run through the boiler from head to head, with nuts outside and inside. The heads are

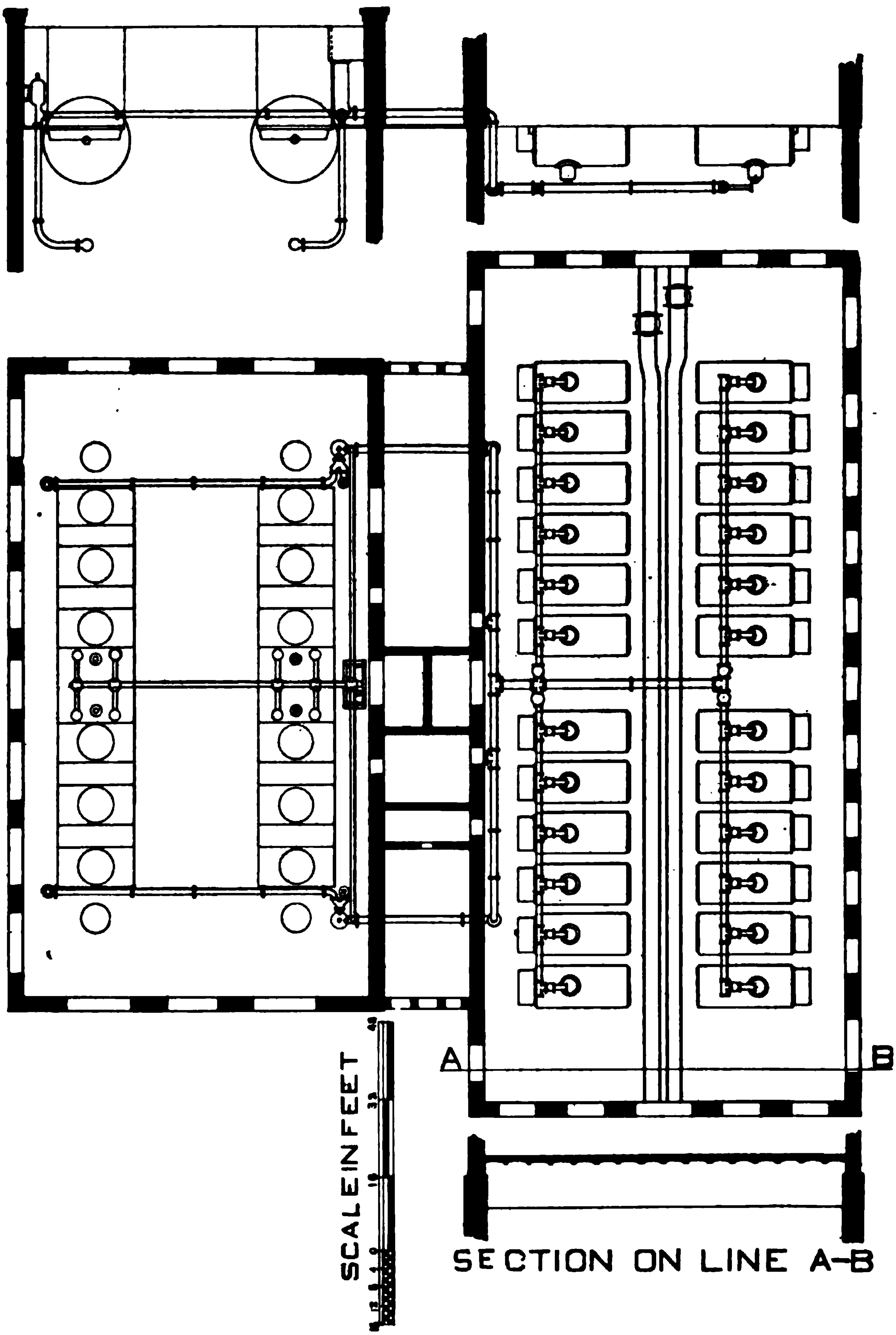
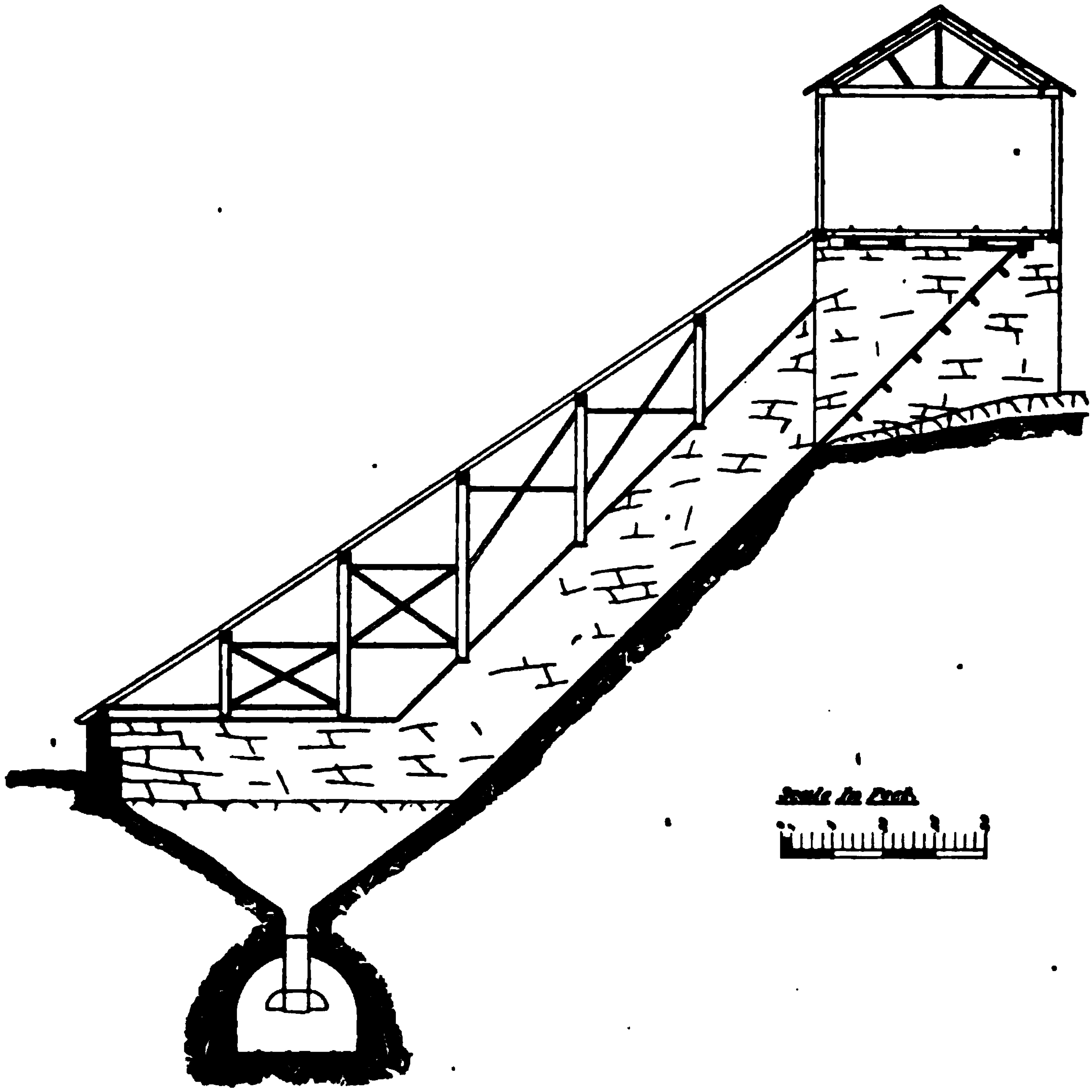
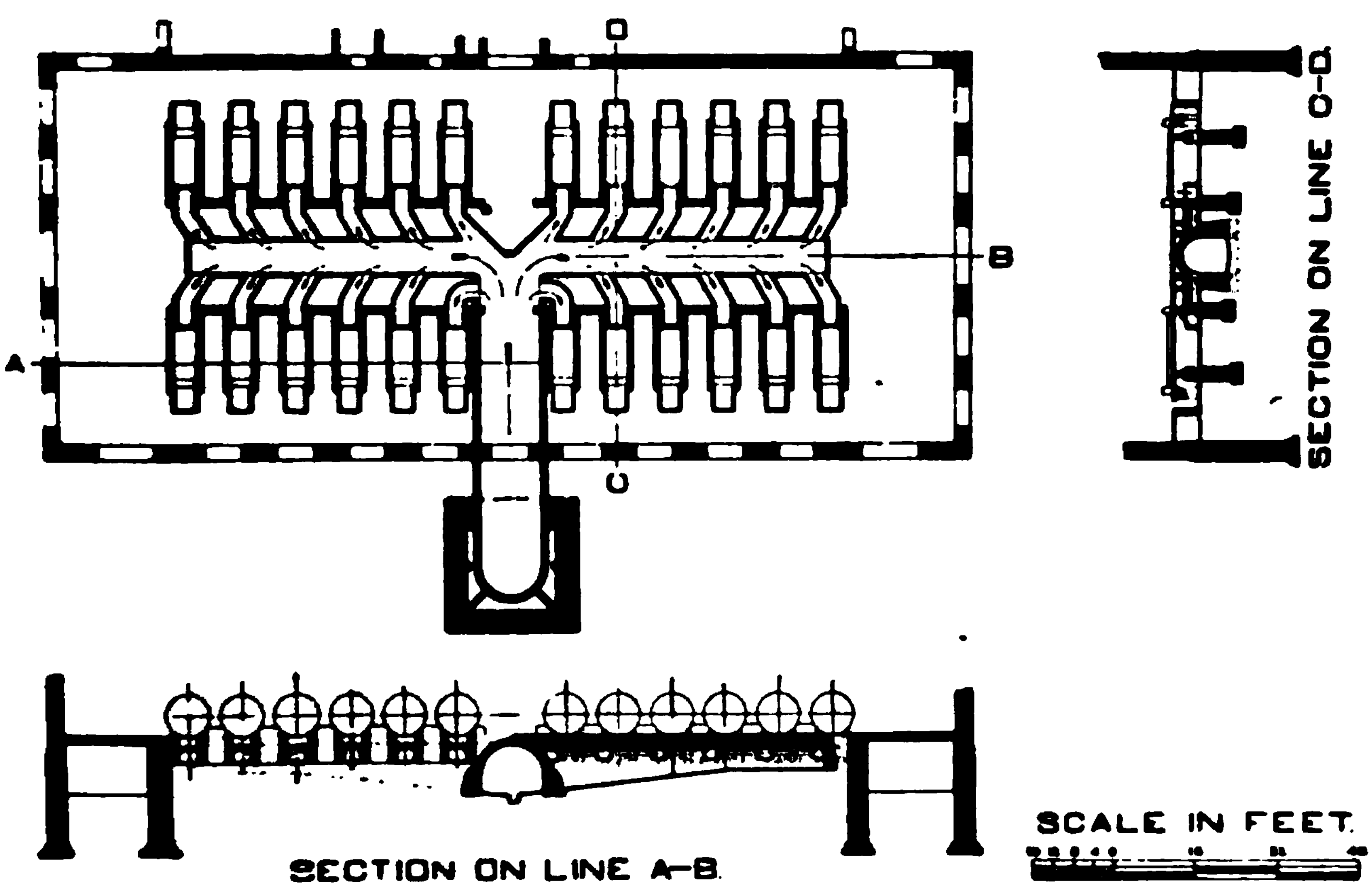


Fig. 2.—Plan of Boiler House and Engine House.



PROPOSED COAL SHED, SHUTE AND TUNNEL.



FLUE SYSTEM.

also stayed with angle irons between the bolts. The manholes are reinforced with $\frac{3}{4}$-inch plate on the inside, riveted to the shell.

The boiler plates for the shell are $\frac{7}{8}$ inch thick; the heads, $\frac{5}{8}$; combustion chamber plates, $\frac{5}{8}$; corrugated flues, $\frac{17}{32}$. Steel rivets were used on all the seams and heads except in such places as required the rivets to be driven by hand, where iron rivets were used. The steel rivets were driven with a hydraulic riveting machine.

Horizontal seams are triple riveted with inside and outside butt straps or cover plates; curvelinear seams are double riveted. The flanging of the heads was done by a specially constructed hydraulic die made for that purpose, so as to finish the work in one operation. The boilers were tested and examined by the writer before leaving the shop in Pittsburg, under a pressure of 220 pounds per square inch. After being set on the foundation at the station they were again, together with the valves and steam pipes, subjected to a pressure of 215 pounds per square inch by the City Bureau of Boiler Inspection.

Fig. 1 shows vertical and horizontal sections of one boiler. The vertical longitudinal section shows the course of the gaseous products of combustion.

The work of raising the 80,000,000 gallons of water per twenty-four hours was designed to be done by four triple expansion engines of 20,000,000 gallons capacity. As shown in Fig. 2, the twenty-four boilers are arranged in four batteries of six boilers each, two batteries being placed on each side of the boiler house. Each boiler has a separate flue, connecting with the main flue under the boiler room floor.

Two hydraulic elevators raise the coal from the basement to the boiler-house floor, and hand cars, running on tracks following the axis of the building, carry the coal from the elevators to the boilers.

The design of the boilers, including the details, boiler setting, brick foundations and flues, the drafting of the specifications, the inspection of material, and the supervision of construction, were the work of the writer.

The engine specifications required 140 pounds steam pressure at the throttle, and as that is some distance from the

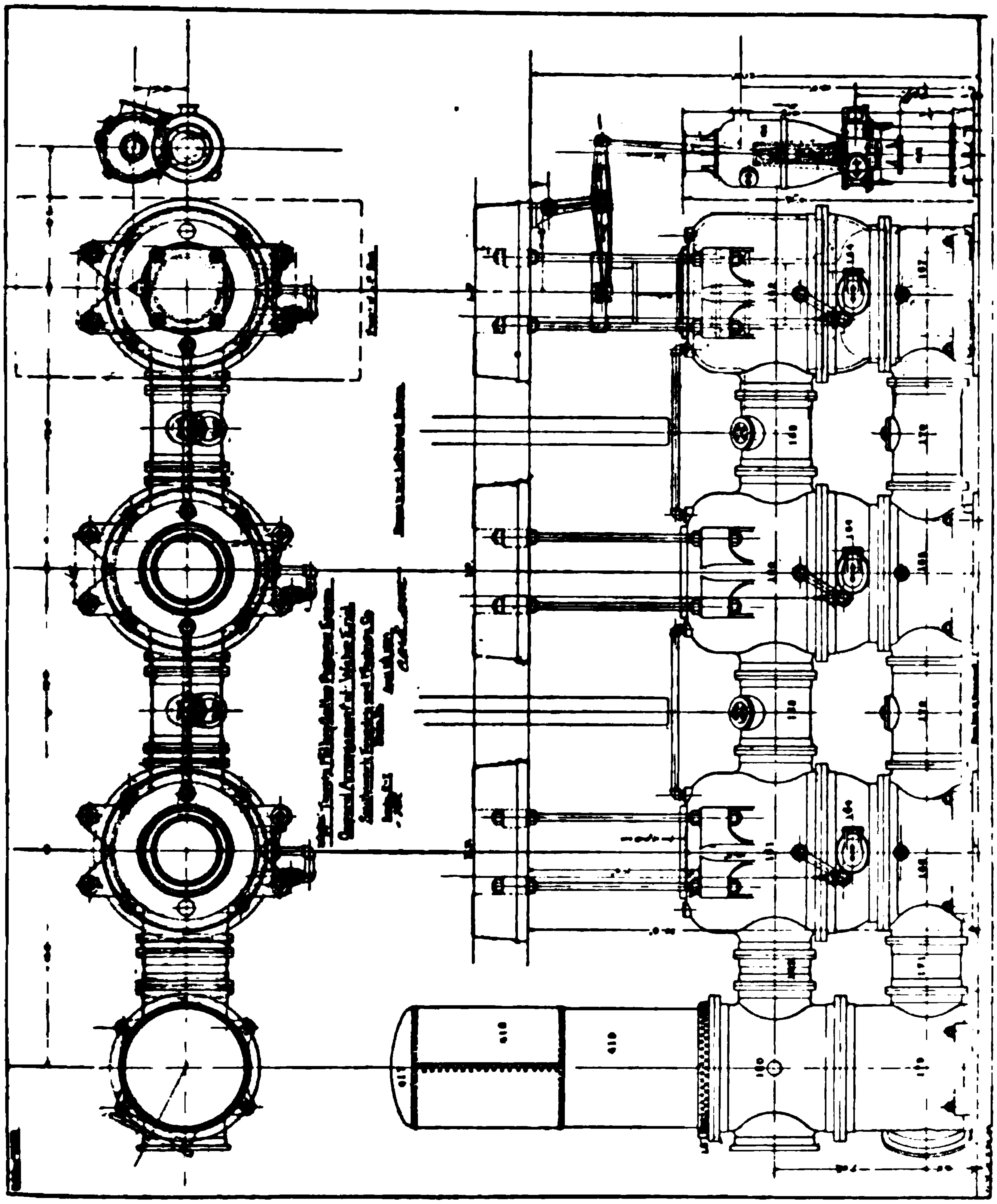
the Southwark Foundry and Machine Company, of this city. They are of the vertical triple expansion type, with single-acting plungers. The contract for the first engine was placed in the latter part of December, 1893, and for the three remaining pumps, in March, 1894. The entire work is now about completed, two of the pumps having been running for several months past on regular work.

These engines are designed to work under an initial steam pressure of 140 pounds, and to pump through a rising main 48 inches diameter about 8,000 feet long, into a reservoir at a height which will give a static head of 250 feet, equal to a pressure, allowing for friction, of about 110 pounds per square inch.

The high-pressure cylinder is 37 inches diameter, the intermediate cylinder 62 inches diameter, and the low-pressure cylinder 96 inches diameter. There are three single-acting plungers, each 34½ inches diameter; they all have a 54-inch stroke. The steam inlet to the high-pressure cylinder is 8 inches in diameter, and the suction and discharge pipes are each 40 inches diameter at the pump, enlarging to 48 inches a few feet away. There is a 48-inch check valve placed in each discharge pipe, and the suction pipes are provided with foot valves. The length of the suction pipes is about 300 feet. The height of the suction lift at the ordinary stage of water in the river is about 17 feet.

Each pump chamber contains 90 suction and 90 discharge valves, with a net area of nine square inches, through each valve. The area of the plunger is 934 square inches and the area through the valves 810 square inches. When the pump is running at 22½ revolutions per minute, which is the required speed to deliver 20,000,000 gallons of water in twenty-four hours, with an allowance of about 3 per cent. for slip, the speed of the water through the valves is 3.6 feet per second.

The admission of steam to the high-pressure cylinder is controlled automatically by a Porter governor, driven by gearing from the high-pressure crank pin. The steam gear is of special design to give the best steam distribution and highest economy; it is particularly simple and accessible for adjustments. The steam valves are of the grid-iron slide pattern, and are actuated by cams, which give quick opening and closing move-



ELEVATION IN OUTLINE OF THE WATER CHAMBERS, SHOWING AIR PUMP AND METHOD OF DRIVING SAME.

ments. These valves are placed at an angle so as to insure their seating, and are held against the seats by the pressure of the steam. Being of the grid-iron type, they have very small movements, and being located in the heads, affords the minimum clearance, not exceeding in any case 2½ per cent. of the piston displacement.

All the cylinders are jacketed with steam, and there are tubular reheaters between the cylinders. The jackets and reheaters, with the exception of the L. P. jacket, use steam at boiler pressure; the L. P. jacket steam is reduced to 50 pounds by means of a reducing valve. All drain and jacket steam is trapped and returned automatically to the boilers.

Each pump is provided with two fly-wheels, 18 feet diameter, and weighing 40,000 pounds each. The air pump, which is single acting, and has a diameter of 28 inches and a stroke of 36 inches, is driven through a beam from the low-pressure plunger crosshead.

The total weight of each engine proper is something at over 1,000,000 pounds, and the total weight of the four pumps, including the piping within the house and the steel substructure upon which they rest, is about 5,000,000 pounds, or 2,500 tons. The total height from the concrete foundation to the highest point of the steam end is, in round numbers, 56 feet, and the extreme length and width occupied by each pump is 46 feet by 18 feet respectively.

A noteworthy feature of this pumping plant is the substitution of steel structural work in place of the usual cumbersome and expensive masonry work for the support of the engines. This construction, which the Southwark Foundry is the first to use, gives easy access to all parts of the water end for examination, and in case of necessity, the pump chambers can be removed and replaced with but little work.

The duty guaranteed is 110,000,000 foot-pounds during a run of thirty consecutive days, with the regular employees of the Bureau of Water, using coal of fair quality.

Should the result of this test be unsatisfactory to either the Director of Public Works, or to the contractors, then the Director of the Department of Public Works, and the contractors, shall

DETAIL OF STEEL SUBSTRUCTURE.

each appoint one expert and these two experts a third, whose services shall be paid for jointly by the city of Philadelphia and the contractors, and under the common direction of the three a new test will be made, and a report signed by two of the experts will be final.

Under the new test the engine or engines will be required to perform a duty of not less than 120,000,000 foot pounds, with 140 pounds steam pressure at the throttle. The equivalent of 100 pounds of coal is taken as 1,000,000 heat units. This test is to last twenty-four hours consecutively.

DISCUSSION.

In reply to a question whether the steel substructure had been used before, Mr. Mirkil said that his company had never used it prior to this plant, and he believed that it is the first time that it has been used by any one.

A member replied that it had been used in building engines, but not very successfully, as it is not as rigid as a cast-iron foundation.

Mr. Mirkil.—It is found to be perfectly rigid; the engines run noiselessly and with little vibration. The pumps have been run up to their full capacity and slightly over, and there is every reason to suppose that it will be as rigid as a masonry foundation. The girders are probably about 4 to 5 feet deep and are very heavy; they were made by the Pencoyd Iron Works.

Mr. A. Falkenau.—I would like to ask Mr. Christie whether a steel structure will vibrate as little as if it were on a masonry foundation.

Mr. James Christie.—There is no question about the rigidity and strength of a riveted girder; in one case the whole frame was riveted work and was always entirely satisfactory; that cast-iron frames will be more rigid is a mistake.

Mr. Mirkil.—(In reply to a question from a member.) The valves are grid-iron, and are placed in bushings in the cylinder heads; the valve seats are on a slight angle.

Mr. Falkenau.—It appears to me that there might be a good deal of clearance by that method of construction.

Mr. Mirkil.—The clearance is in no case greater than 2.5 per cent. and is the same above as below; the plunger speed is about 200 feet.

Mr. Christie.—There has been a marked improvement in the economy of pumping engines during late years, due to the use of high-pressure steam and multiple expansion. A duty of 140,000,000 foot-pounds per 100 pounds of fuel consumed, is reported in several instances, and by the use of controlled water valve gear, and a piston speed of 400 feet per minute, it is probable that a duty of 150,000,000 is feasible. It will be remembered that thirty years ago a duty of 100,000,000 was obtained only on a few Cornish engines under exceptional conditions. It is probable that the best pumping engines throughout the country at that time did not yield an average duty of 50,000,000 foot-pounds.

PART III.—THE ENGINE AND BOILER HOUSES.

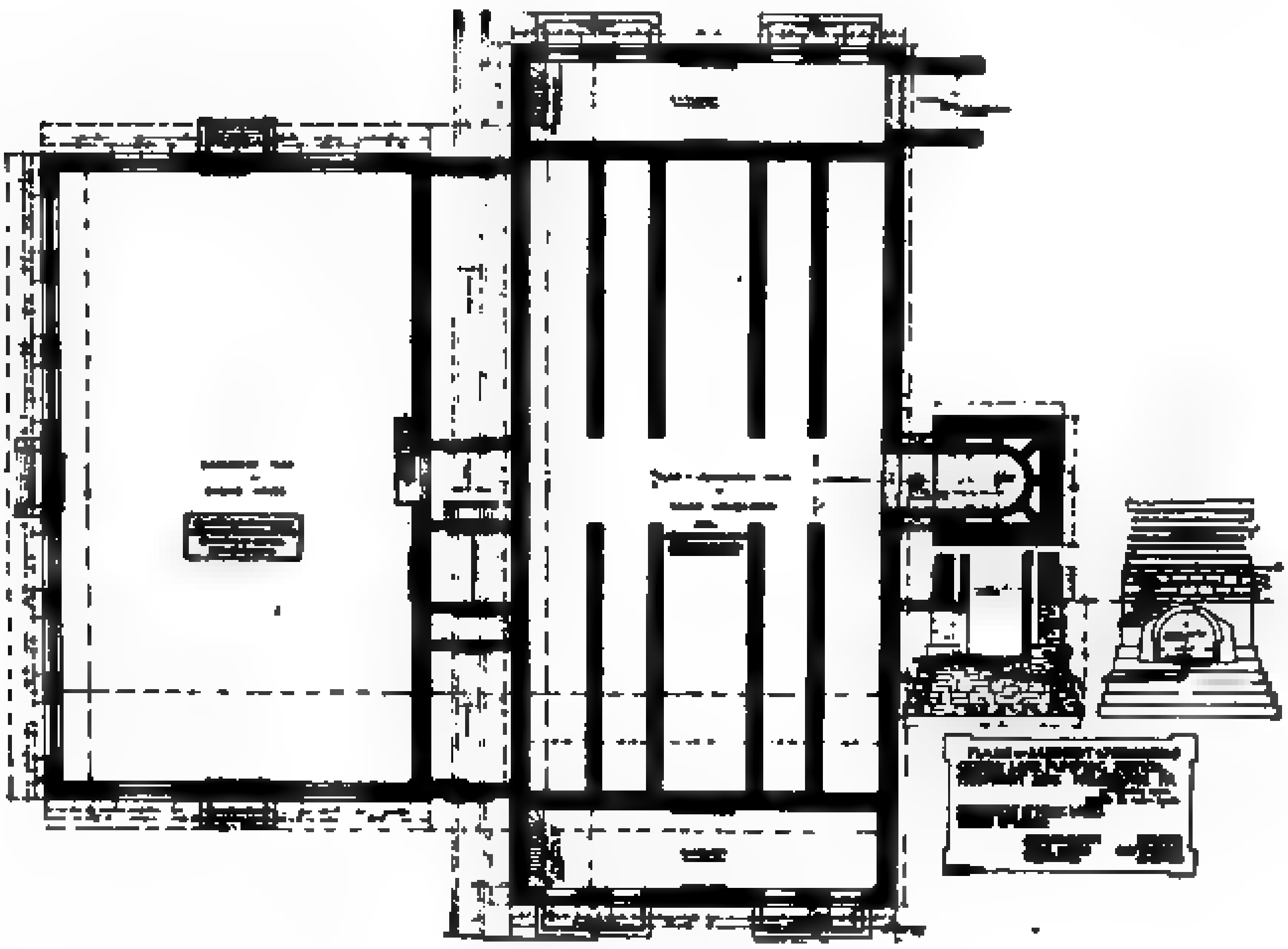
By F. L. Hand, Active Member of the Club.

Read February 15, 1896.

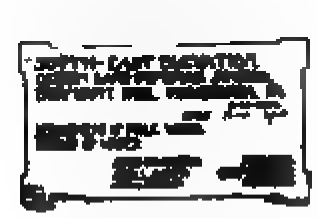
The Queen Lane Pumping Station is located in East Fairmount Park, midway between City Avenue Bridge and School Lane Station on the Reading Railroad.

The original design for these buildings provided for the erection of two stacks, and the use of Hummelstown brown stone and red brick. According to this plan the engine house was to have been 158 feet long by 81 feet wide, with a height of 48 feet from floor to roof-plates. The boiler house was to have been 181 feet long by 81 feet wide, and 36 feet from floor to roof-plates. The intermediate building was to have been 158 feet long by 15 feet wide, and 26 feet high. The stacks, as designed, were to have been 150 feet in height, with an inside diameter of 9 feet. Starting from a square base of 18 feet, at a height of 53 feet there was to have been an octagonal superstructure 16 feet from out to out, tapering to 12 feet from out to out.

These buildings were contracted for at a price of $152,420, but as the design failed to meet the approval of the Park Commission, they were not erected. The main objections given by the Com-



General Foundation Plan.



Southeast Elevation.

HAND—THE QUEEN LANE WATER WORKS.

STACK DURING CONSTRUCTION.

BUILDING AS FINISHED.

72 feet long by 16 feet wide. The sashes have a ratchet opening attachment, operated from the floor of each building.

The external walls of the buildings are enriched with belt courses, arch mouldings and foliated terra-cotta frieze. A large granite tablet, 15 feet long by 8 feet high, set in terra-cotta ornamentation, occupies the center space over the door in the front wall. The cut stone used in the buildings is Indiana limestone.

The floor of the engine house is constructed of yellow pine beams, 6 inches by 12 inches, spaced 3 feet from center to center, on which is laid 3-inch slip-tongue flooring.

The floor of the boiler house and of all the basements is composed of cement concrete with a granolithic finish.

There is provision in the engine house, at a height of 42 feet from the floor, for an electric traveling crane, with a clear span of 75 feet. It has a lifting capacity of 20 tons and has assisted materially in facilitating the work of erecting the engines. The lifting tackle can be placed over any point in the engine room, except a narrow space around the walls.

The stack is built central to the front wall of the boiler house, but separated from it by a space of 9 feet. The inside diameter of the barrel is 12 feet and it rises to a height of 201 feet above the ground in front of the building. The external wall of the stack is built in the form of a tower with a base 27 feet square. At a height of 181 feet, where the tower ends, it is 24 feet on a side. The foundation of the stack is about 24 feet below grade level, the bottom course being 37 feet square and 2 feet thick, the stepping courses averaging 18 inches in thickness. There is a cut stone base, 6 feet in height from the grade level. All the superstructure is built of hard stretcher bricks, faced externally with buff bricks. The top of the tower portion of the stack, for a height of 38 feet, is decorated with terra-cotta moulded brick pilasters, with foliated caps, and an ornamental balustrade. On the four sides of the stack below the main cornice there are ornamental panels, 14 feet high, by 11 feet wide, in terra-cotta enrichment.

The intercepting sewer passes directly under the center of the intermediate building, and connections from all water-closets and baths, which are located entirely in this building, are readily made and easily accessible.

It was intended to use wired-glass lights in the ventilators on the engine and boiler house roofs, but after using it in the boiler house ventilator, it was found to crack, due probably to changes in the temperature. A heavy corrugated glass was substituted for wired glass in the engine house ventilator.

DISCUSSION.

MR. FRANCIS SCHUMANN.—I desire to say a few words about the wire-glass alluded to by Mr. Hand. This material is the product of a Philadelphia invention; it consists essentially of inserting woven wire, of larger or smaller mesh, as may be desired, in the middle of sheets of glass, when in process of manufacture. The woven wire, or "wire-cloth," so inserted, binds the glass and thus prevents the sheet from separating when broken, and consequently removes the danger from broken pieces to people underneath. The older method of lessening this danger, when ordinary glass is used in roofs or floors, is to stretch wire-cloth immediately underneath the glass; this is expensive and seriously interferes with the cleaning of the glass.

In its manufacture there were difficulties at first in annealing, but they have now been overcome. Perfect annealing, by the way, is of vital importance in glass, and specially so in wire-glass.

Wire-glass is now made most successfully, both in England and Belgium, under the Philadelphia patents, the manufacturers there readily overcoming the difficulties of annealing.

By reason of imperfect annealing, in some of the glass made in this country, and placed in buildings, cracks soon appeared, and justly caused complaint. Notwithstanding the cracks it is a remarkable fact, noted by those using it, that the glass does not leak, although used but slightly inclined to the horizon.

The well known resistance of glass to heat, and its non-conducting properties, will make wire-glass an important factor for window openings in buildings exposed to fire from adjacent structures.

I would call attention to the fact that it is not safe to bed heavy glass directly on iron. There should be some soft or yielding medium, such as wood, rubber or rope, laid upon the iron frame for the glass to rest upon. A prolific cause of fracture is when

the outer edges of the glass bear upon the iron, or when there is a lack of clearance between the edges of the glass and the standing ribs of the surrounding frame. Fracture is induced by any hard substance, such as iron, tending to abrade the corners of the edges, where the glass is most vulnerable; the action causing abrasion being from expansion and contraction between the glass and the supporting frame. When glass is laid directly upon the iron, care should be taken to insure ample clearance at the edges and that the bearing is within, alongside of the edge; aiming to free the edge from contact with the iron.

That fracture in wire-glass is not due to any variations of expansion or contraction of the glass and wire, is evident from the following: The usual size of sheets is about 36 inches wide by 72 inches long and ¼ inch thick. The most closely woven wire-cloth used is of No. 28 wire, with meshes ½ inch square, making say 72 wires running longitudinally with the sheet. The No. 28 wire is 0.014 inch diameter, equal to 0.00019 square inch area, having an ultimate strength of 180,000 pounds per square inch. The total ultimate resistance of the wires to tearing, would be: $0.00019 \times 72 \times 180{,}000 = 2{,}462$ pounds. The sectional area of the glass that resists this pull of 2,462 pounds, were the variations such as to cause fracture, is $36 \times \frac{1}{4} = 9$ square inches. Assuming the resistance of the glass to crushing to be 6,000 pounds, its lowest value, the total resistance would be $9 \times 6{,}000 = 54{,}000$ pounds or nearly 22 times greater than the strength of the wire.

As the wire, in the process of being inserted in the hot glass, immediately acquires the same temperature of the surrounding glass, because of its rapid conductivity, it increases in volume, expanding the glass, yet semi-fluid, accordingly; then, when cooling, the wire, due to its greater contraction, shrinks away from the glass, leaving an annular clear space between the wire and the glass. Hence the wire cannot have any effect upon the glass by reason of any variation in expansion or contraction.

MR. A. FALKENAU.—Did the glass give out after it was put up?

MR. HAND.—Yes, in each case. We had a great many defective sheets in the fire room; it cracked with changes of temperature of the atmosphere.

MR. AMASA ELY.—Nineteen sheets of this glass had cracked

shortly after it was put up, and in two or three weeks the number was increased to about forty. The first number of sheets were replaced by the makers.

MR. HAND.—During the heavy rains of last week the cracked wire-glass in our boiler-house did not leak a drop.

MR. JAMES CHRISTIE.—I have had occasion to put up a great many thousand feet of glass skylight, and have never used any sort of fibrous material, nor have I had any trouble with glass breaking except from external causes.

DR. HENRY LEFFMANN.—The breaking of glass when in even light contact with iron and other hard metals, is frequently observed, and is doubtless due to unequal annealing and not to pressure or strain.

IV.

WATER RENAISSANCE.

By JOHN BIRKINBINE, Active Member of the Club.

Read March 7, 1896.

THE French word "renaissance" is used in the above caption as covering by general acceptation somewhat broader ground than the word "revival," or, possibly, than our English equivalent "renascence," to indicate the scope of some notes, which are presented on the assumption that we are in an era when engineers may be expected to be called upon, more than in the late past, in connection with the employment of water in various ways.

Water played a most important part in the development of nearly if not all of our industries and in the transportation of large weights or volumes. The water-wheel was the principal motive power for manufactories from which the crude metals or their refined products were obtained, when the force required was greater than manual or animal labor could advantageously supply, until the general application of steam. Similarly, the canal was the medium for the conveyance of materials or products whose weight or volume could not be economically transported by animals or wheeled conveyances, until the advent of the railroad and its expansion to cover large territory.

Water wheels have continued to be employed, but the forms of motors have been much improved. The flutter, current, undershot, overshot and breast wheels have given place to turbines on horizontal or vertical axes revolving at high speeds, and working under heads which a few decades ago would have been rated as impracticable. Water wheels have disappeared from many localities, either because of the changed conditions of trade and transportation or because the value of power sites has depreciated by reason of the denudation of timbered areas on the water sheds, decreasing the reliability of streams. We are evidently on the eve of a considerable revival of interest in water powers, many which have lain dormant for years, or from which the exigencies of trade have driven the mill and factory, may be

expected to be improved, and possibly a number of them combined, to furnish power by means of electrical or compressed air generation and transmission.

In the discussion upon the paper presented by Mr. J. N. Powell, and that by Mr. F. H. Newell, I took occasion to refer to the possibilities of the enlarged application of the use of water for power, due to the possibility of the location of electrical generating plants on streams, and to the application of this power elsewhere, and also to the possibility of an increase in the field for irrigation in districts which cannot be classed as in the arid belt. From various parts of the country, and also from foreign lands, come records of what the engineer is doing in the development of water powers by the construction of dams, the improvement of motors, the generation and conveyance of power in units heretofore considered impracticable, and one cannot read the technical, or even the public press, without realizing, that as far as application of water as a power is concerned, there is certainly a revival of interest.

Somewhat similar conclusions could be reached in regard to the collection and use of water for city and domestic use, and while asserting a firm belief in the value of filtration (properly applied and cared for), I consider that it is better to obtain a supply of water from a source as nearly pure as possible, and if filtration is then required for this, the amount of money or the space demanded for these filters will be much less for the same volume of more impure water. The construction of reservoirs or dams are no more serious problems than those of building bridges or tunnels, but any reservoir or dam which is not conscientiously and thoroughly constructed from excavation for the footing of the embankment puddle or retaining walls, to the final completion of the work, jeopardizes large interests and may result in serious damage.

The rainfall on the Schuylkill water shed is equivalent to the delivery at Philadelphia of a daily flow of 4,000,000,000 gallons. Under existing conditions, but about half of this reaches Philadelphia, and much of what does come to the lower portion of the stream passes away in time of freshet, so that the average daily flow represents but about one-tenth of the quantity of water

which falls on the Schuylkill water shed, and during the drought of last summer it is reported that less than 200,000,000 gallons per day passed into the Fairmount pool. The investigation of the Susquehanna floods has demonstrated that nothing will do so much towards reducing the damage from this cause as the reforesting of certain waste areas on its head waters, and the same applies to all of our streams.

The revival of interest in the application of water, may also well be considered as embracing the irrigation problem, which seems destined to reach into regions where, under ordinary conditions, the storage and delivery of water for agricultural purposes would not be expected. In the Dakotas, Nebraska, Kansas and elsewhere, hundreds of artesian wells are sunk, from which water is drawn by pumps, and distributed to crops, particularly those from which a supply of fruit and vegetables are expected, and the question may come before the citizens of Pennsylvania whether or not it may be advisable to use engineering talent sufficient to provide a means of supplementing a copious uncertain rainfall by artificial water supply which can be called upon in times of drought. Frequently in our climate the farmers or truckers of Eastern Pennsylvania find that the continuation of a dry spell for two or three days may mean the difference between a satisfactory return for the crop planted, or a complete failure. Undoubtedly a practically continuous supply of water adds to the growth and perfection of any crop planted and cultivated.

The remains of a formerly extensive canal system are left, but with a few exceptions these avenues of commerce have been allowed to pass into the control of railroads, whose purchase or absorption and subsequent suppression is the best evidence that they were dangerous competitors. Some now operated show that this competition is a reality, and the State of New York owes to its canal system much of the progress which entitles it to be known as "the Empire State."

If the canals of limited capacity which a few decades ago were in use, and the few which now exist, are competitors with railroads, what might have been their status if a portion of the engineering skill which has been devoted to the construction and improvement of railroads, had been bestowed upon the bet-

The extensive improvement of our rivers and harbors, by which deeper channels are provided to meet greater draught of vessels, may also be considered as a feature in the water renaissance. The removal of the islands in front of Philadelphia, the change in cross-section of the channel requiring the excavation of 22,000,000 cubic yards of material, and the proposed improvements of the lower reaches of the river, are familiar to us, while in various parts of the country large and important works on river and harbor improvement are under way.

The use of water in hydraulic dredging, in sinking large caissons, the removal of great masses of material by hydraulicking as practiced in California, and the application of water under very high pressures in forging and other lines of work, may be considered as indications of a water renaissance. Nor must we omit the fact that some of our industries demand supplies measured by millions of gallons daily, and that one of our great steel works will, for their furnaces, mills, etc., require as much water as a city.

The possibilities which are before us may be appreciated by a few figures concerning the quantity of water which falls upon a given area, much of which can be placed at our disposal. In the eastern part of the State of Pennsylvania the average rainfall is from 42 to 45 inches per annum; reduced to weight and wheel, this means that from 2,700,000 to 2,900,000 gross tons, or from 97,500,000 to 104,500,000 cubic feet are annually precipitated on each square mile. If this quantity of water could all be collected and controlled so as to be discharged continuously, and the discharge distributed over the entire year, it would equal a flow of from $3\frac{1}{10}$ to $3\frac{1}{3}$ cubic feet per second per square mile. If we take the entire area of Pennsylvania (about 45,000 square miles) and compute the weight and volume of the possible flow-off from this entire area, we would have figures which would be startling.

It is, of course, impossible to either collect, store or utilize all of the water falling on a given area, and the proportion which can be so applied is influenced by the geological and topographical conditions and also by the proportion of the land which is in forest. The precipitation of the rain is neither continuous nor

area as great as that of the Schuylkill River basin, from which most of the forests have been denuded, it is possible that it would be necessary to allow 40 square miles of water shed to produce 1 horse-power per foot of available fall. These figures are merely offered as suggestive, for the possibilities of any improvement of water powers will be dependent upon the selection of a suitable drainage basin, its geology, topography, and stratigraphical conditions, the judicious location and construction of impounding dams and reservoirs, and the proportion of forest growth.

In considering the possibilities of water supply for municipalities, a somewhat more liberal percentage of utilization may be provided for, as it will be practicable under ordinary conditions to devote a larger amount of money to the storage of water than where it is to be used for power. Taking the average rainfall in Eastern Pennsylvania, it is found that sufficient water falls on a square mile to give a flow of 2,000,000 gallons per day throughout the year. Now, if it were possible to collect and store all of this, the city of Philadelphia would not demand a drainage area of more than 100 square miles to give it as much water as is now used. But these areas are not an impervious basin nor are the streams draining them closed pipes, hence there is more or less loss to be accounted for; but it may be possible, in well-timbered areas, near the head waters of some of our streams, to utilize from each square mile a daily flow of from 1,250,000 to 1,500,000 gallons of water. Following further down the stream, the proportion of collectible rainfall decreases, and the prominent tributaries of our rivers which drain areas of considerable extent from much of which the forests have been cut off, can hardly be depended upon for 700,000 gallons per day.

The same reasoning might be applied to the irrigation problem, to which the United States Government has fortunately devoted a great deal of attention and upon which volumes have been issued by the United States Geological Survey. In fact the latest contribution, "The Public Lands and Their Water Supply," deals directly with the relation which forest cover bears to the irrigation problem.

From what has been said, it would seem that the water renaissance will have for one of its factors the maintenance of existing,

or the creation of new forest areas; and the present interest in the forestry movement, which is pronounced in our own State, and in most of the States of the country, shows that the people are awakening to an appreciation of its importance. The General Government has established forest reserves, New York and Massachusetts have followed in the same line, while Pennsylvania, New Jersey and other States are agitating the policy of maintaining a liberal area of forests on the head waters of the streams.

An editorial appeared in a late issue of *Harper's Weekly*, which, while treating only of water renaissance as power, is applicable to the other problems and furnishes a fitting ending for these notes, and as such it is quoted: "The subject is not one of quixotic theory; it is sober, scientific, demonstrable. One may easily be beguiled by the crowd of dazzling possibilities which crowd on the mind from a casual outlook on this new field of economic speculation. But the hard facts, when measured and weighed, justify the belief in rapidly coming changes, which will make an epoch in the progress of industry, through this curious return to the primitive force which man first yoked to his own in a semi-barbaric state."

NOTES AND COMMUNICATIONS.

REPAIRS TO THE QUEEN LANE RESERVOIR.

At the meeting of January 4, 1896, Mr. John C. Trautwine, Jr., active member of the Club, exhibited a number of lantern slides illustrative of the Queen Lane division of the city's water-works, with special reference to the repairs recently made on the reservoir. The series embraced plans of the system as a whole, and of the engine and boiler houses and reservoir, a profile of the pumping main, a cross-section of the concrete footing wall constructed around the foot of the inner slopes in the south basin, and photographic views of the pumping plant and the reservoir. The views of the reservoir illustrated the operations connected with the construction of the footing wall and with the application of melted asphalt in sealing the cracks in the surface of the concrete slabs forming the inner slopes, the joints between the slabs, and such cracks in the floor as seemed to require attention.

Before the repairs, the daily loss of water from leakage and evaporation combined, under a head of six feet, amounted to half an inch in the north basin, and one inch in the south basin. After the repairs, under the same head, the loss from both basins ranged from $\frac{1}{10}$ inch to $\frac{1}{4}$ inch per day.

For several weeks water had been pumped into the reservoir from the new pumping station, and the volume thus stored was utilized to relieve the direct pumpage district from the necessity of using the coal-dust-polluted water flowing in the Schuylkill. The slides exhibited form a portion of those which will accompany a series of papers on this system.

SUBURBAN SEWAGE DISPOSAL, AND THE SEWERAGE PLANT AT WAYNE, PA.

At the meeting held on March 21, 1896, a paper on the above subject was read by Mr. Thomas G. Janvier, active member of the Club.

The speaker stated that the general problem of sewage disposal in suburban towns was a most serious one, and one that usually did not receive the attention its importance deserved. The evils of the common well or cesspool method were pointed out and various modern systems of sewage disposal were briefly referred to.

A detailed description of the sewage disposal plant at Wayne, Pa., was presented, the data of which were credited to a publication by Col. G. E. Waring, the designer of this plant. The paper was illustrated by lantern views.

MODERN METHODS OF SEWAGE DISPOSAL.

At the meeting held on March 21, 1896, an informal talk, illustrated by lantern views, was delivered by William Easby, Jr., active member of the Club, on the subject of Sewage Disposal.

Statistics were presented, showing the rapid growth and increasing ratio of urban population, in illustration of the growing importance of the sewage disposal question.

Attention was called to the marked decrease in the death-rate from typhoid fever, following the introduction of improved systems of sewerage and water supply.

The system at Boston was referred to as one of the most successful examples of sewage disposal by dilution.

The broad irrigation systems at Berlin, Ont., and at Pullman, Ill., were described, and it was stated that the former should more properly be classed with the filtration systems. The ridge and furrow system of irrigation, as practiced extensively in England, was also described.

The filtration method was illustrated by reference to the filter-beds at Summit, N. J., and at South Framingham, Mass.

The chemical processes in use at Canton, O, and Long Branch, N. J., were mentioned in conclusion.

IMPROVEMENT OF WATER SUPPLY.

An Experimental Strainer for Grossly Polluted Water.

At the meeting of March 21, 1896, Mr. John C. Trautwine, Jr., active member of the Club, described a small experimental filter that had been set up near the Spring Garden pumping station to see what could be done, by rapid straining, to improve the appearance of the water furnished to the "direct-pumpage" district. A cast-off separator, 4 feet in diameter, was fitted with a perforated false bottom and with pipes for bringing in and discharging the water. A bed of coal ashes about 3 feet in depth was placed in it, and when the black water charged with coal-dust brought down by the recent rain-storm was passed through this simple device, the discharge at the lower end was sufficiently improved to be fairly acceptable for wash-day purposes. The average rate of flow corresponded at first to about 90,000,000 gallons per acre per day, but fell off rapidly as the bed became clogged. No precautions had been taken to allow the access of air above the filtered water, and the rate therefore probably suffered somewhat from the formation of a vacuum.

Filtration vs. Sedimentation.

In the recent discussion in City Councils on the appropriation to establish a filter plant, it was urged by some Councilmen that sedimentation would be as effective as filtration, if not more so. To experiment upon this, the smallest basin of the East Park Reservoir was shut off, and the water was tested chemically and bacteriologically, from day to day, by Dr. A. C. Abbott, of the University of Pennsylvania. The sample taken after twelve days of sedimentation shows considerable clarification, but far less than would result from proper filtration. Sedimentation and filtration both appear to have but little effect upon the chemical composition of water.

A table was exhibited, showing the bacteriological effect of sedimentation and of filtration as found in London and elsewhere, and in the recent experiments at the East Park reservoirs. In the latter instance the number of microbes in a cubic centimeter was reduced by sedimentation, in two days, in the ratio of 1000 to 131, and no marked change either way was observed after that time. In London, sedimentation reduced the number in about the same proportion, while filtration, as is well known, removes from 95 to more than 99 per cent. of the bacteria.

The Typhoid Rate.

In a recent editorial in *Engineering News*, favoring a filtration plant for this city, a rather damaging and somewhat incorrect statement about the health of our city was made, based upon the prevalence of typhoid fever during the Centennial. Mr. Trautwine exhibited a diagram constructed from figures furnished by our Bureau of Health, covering the years from 1861 to 1895, and showing the number of typhoid deaths per 100,000 persons living. During the Civil War and during the Centennial, our actual population was greatly swelled by temporary residents who do not appear in the divisor used in obtaining the ratio. In the latter case the weather was unusually hot, a large proportion of the population were physically exhausted by sight-seeing and over-crowding, and the sanitary conditions at the Exposition grounds were defective. Since the completion of the intercepting sewer for the protection of the Fairmount pool, in 1888, and the final abandonment of the Otis Street pumping station, in 1890, there has been a marked, and apparently permanent, decrease in the number of deaths. Figures furnished by the Board of Health show that the number of deaths in proportion to the number of cases has steadily decreased, indicating, as pointed out by Dr. Leffmann, that we now understand better how to take care of this disease.

Private Filtration.

In the discussion, Mr. James Christie stated that in investigating the subject of filters recently, he was surprised to find what an immense number of private filters are in use in Philadelphia, of capacities ranging from 5 to 20 gallons per minute, supplied on a large scale by at least six different manufacturing concerns. All hotels, hospitals, etc., have them, and the use of filtered water among the better class of residents is very common. In a laundry which was visited a filter was used having a capacity of 15 gallons per minute, the purification being aided by the use of a coagulant and the reversal of the filter.

In old Philadelphia it was a common practice for the women of the families to tie a piece of cloth over the hydrants to strain the water, and the organisms collected at that time were by no means microscopic. The water that was used 30 years ago in some parts of Philadelphia would not be tolerated now. At the time of the cholera epidemic in 1866 the greatest number of cases were in the district supplied by direct pumpage from the old Kensington water-works, which have since been abandoned. Mr. Edwin F. Smith explained that at the Reading Railroad depot the water used is filtered with the aid of alum as a precipitant. The maximum capacity of their filter is 10,000 gallons per hour. When the supply in the mains is very dirty, the water is filtered for the boilers and the alum has to be left out.

COMMITTEE ON INFORMATION.

The Committee on Information reports as follows:

In its efforts to obtain valuable papers for presentation to the Club, the Committee has met with gratifying responses from the members, and has also to acknowledge the welcome and valuable contributions of non-members, who were invited to address the Club. The following is a list of the papers presented during the year:

JANUARY 5.—The United States Geological Survey, and its Methods of Work. By Charles D. Walcott.

JANUARY 19.—Annual Report of the Directors.—Address of the Retiring President. By John C. Trautwine.

FEBRUARY 2.—Investigation and Experiments for the Determination of the Groove in Guard Rails for Street Railways. By Victor Angerer. A Communication Concerning the Proper Form of Rail for Street Railways. By Wilfred Lewis.

FEBRUARY 16.—A Problem in Hydrostatics and its Ingenious Solution. By C. H. Ott.

MARCH 2.—Topical Discussion. The Promotion and Improvement of Rapid Transit in Philadelphia. Opened by Wm. Wharton, Jr.

MARCH 16.—Memorial of the late Samuel L. Smedley. Silver Mining in Mexico. By C. B. Dahlgren.

APRIL 6.—Method and Results of Measurements of Stream Discharges, made by the United States Geological Survey. By F. H. Newell.

APRIL 20.—Electrical Heating. By J. Chester Wilson.

MAY 4.—Coffer-Dams. By William H. Dechant. Railway Construction in the Peruvian Andes. By James R. Maxwell.

MAY 18.—Wreck of the Connersville Bridge and its Temporary Repair. By Joseph Kemper.

JUNE 1.—Certain Interesting Features in the Manual Interlocking of Railroads. By Geo. H. Paine. The First Horizontal Turbine ever Built. By Emil Geyelin.

JUNE 15.—The Philadelphia and Reading Coal Storage Plant. By William D. Beatty.

OCTOBER 5.—Submerged Pipe Line for the Pennsylvania Sanitary Sewerage Company of Reading, Pa. By William H. Dechant.

OCTOBER 19.—Discussion on the Durability of Iron in Modern Building Construction. Opened by W. C. Furber.

NOVEMBER 2.—Water Supply of Rome. By Henry Leffmann.

NOVEMBER 16.—Paint as a Protection for Iron. By E. A. Custer and F. P. Smith.

DECEMBER 7.—Notable Engineering Achievements in the Great Lake Region. By John Birkinbine.

DECEMBER 21.—Mines and Plant of the El Carmen Mining Company, Villaldama, Mexico. By Harrison Souder.

A number of these papers were illustrated by lantern slides, besides which members have at various times exhibited slides of engineering works completed or in course of construction. This feature is worthy of encouragement, as it adds greatly to the interest of the meetings.

The feeling has been generally expressed among the members, that since electricity was becoming of constantly increasing importance, as applied to engineering, it should receive more attention at the Club. This induced the Committee to arrange

for a series of practical talks on electricity on Saturdays alternate with regular meetings, as follows:

OCTOBER 12.—Electric Energy, Terms, Properties and Calculations. By Carl Hering.

OCTOBER 26.—Electric Lighting Installations. By Thomas Spencer.

NOVEMBER 9.—The Electric Transmission of Power. By C. W. Pike.

NOVEMBER 22.—Electric Traction. By Charles Hewitt. This was followed by a visit to the Beach Street Power House on November 23d.

DECEMBER 14.—Electro-Chemistry in its Practical Relations. By E. K. Landis and Henry Leffmann.

These preliminary talks are to be followed by the presentation of papers of a more scientific character at the regular meetings. This undertaking has proved a gratifying success, as shown by the large attendance, which almost equalled that at regular meetings.

FINANCE COMMITTEE.

The Finance Committee reports, that the net balance of the old indebtedness amounting to $1,170.61, has been paid off, and an extra expenditure of $463.79 was made for new carpets and improvements, all of which was done from the regular income of the year; and after deducting the amount for new carpets, etc., the expenditures for the year were $0.57 more than the estimate made for the year by the retiring Board on December 31, 1894.

Our collections for dues for the current year were $627.50 more than for 1894, and the collections of back dues for 1894 were $187.50 more than the collection during the year 1894 for back dues of 1893. This would indicate the good work of our Treasurer. Our balance-sheet shows a surplus of assets over liabilities of $393.21, this being a decided improvement over the preceding years, as is shown by the report for 1894, where the liabilities exceeded the assets $625.44 for the year ending December 31, 1894, and $1,693.80 for the year ending December 31, 1893.

BALANCE SHEET.

Assets.		*Liabilities.*	
Amount due for advertising	$285 50	Stern & Co.	$330 29
" " " Proceedings	9 50	Sherman & Co.	37 50
" " " Reprints	17 00	H. Veit	74 00
" " " Dues of 1894	10 17	Rent	275 00
" " " Dues of 1895	450 00	Ice	18 25
Cash on hand, Dec. 31, 1895	390 21	C. L. Prince	6 25
		Williams, Brown & Earle	2 30
	$1,162 38	Edison Electric Light Co.	9 33
		McFarland & Co.	11 25
		Prepaid Dues for 1896	5 00
		Total Liabilities	$769 17
		Balance of assets	393 21
			$1,162 38

ESTIMATES AND EXPENDITURES BY THE FINANCE COMMITTEE.

	Estimate for 1895	Expenditures for 1895	Estimate for 1896
Salaries	$1,105 00	$1,105 00	$1,200 00
Proceedings	1,000 00	903 38	1,000 00
House	1,400 00	1,336 40	1,400 00
Luncheons	550 00	607 00	600 00
Notices	425 00	362 43	450 00
Secretary's Office	225 00	164 26	250 00
Treasurer's Office	15 00	40 35	50 00
Library	30 00	78 40	250 00
Information Committee	75 00	142 00	150 00
Sinking Fund	465 53	465 53	....
Miscellaneous	15 00	39 00	50 00
Liabilities, Dec. 31, 1895		769 17	
	$5,305 53	$6,012 92	$5,400 00
House improvements	....	463 79	
		$6,476 71	
Less Liabilities, Dec. 31, 1894	....	1,170 61	
Total expenditures for 1895	....	$5,306 10	

PUBLICATION COMMITTEE.

The Publication Committee received at the beginning of the year two bids for printing the PROCEEDINGS of the Club, and after giving them full consideration, renewed the contract with the Globe Printing House on terms slightly more advantageous to the Club than for the preceding year.

Since its last report, the Committee has issued four numbers of the Club's PROCEEDINGS, containing a total of 365 pages of printed matter, exclusive of advertisements, being an increase of 73 pages as compared with the corresponding numbers for the preceding year. Each number has been issued on time.

Proceedings.	Cost of Printing.	Cost of Illustrations.	Postage.	Total.
Volume XI, No. 5	$182 43	$23 01	$8 30	$213 74
" XII, " 1	225 12	42 70	23 48	291 30
" XII, " 2	190 45	72 75	9 30	272 50
" XII, " 3	93 92	14 30	7 95	116 17
Totals	$691 92	$152 76	$49 03	

Total for printing, illustrating and postage	$893 71
Reprints	62 75
Wrappers	16 00
Copyrights	4 00
Sundries	7 80
Total cost of Proceedings	$984 26

parlors. A new tub has been supplied for the bath-room. The gas fixtures have been arranged so that the light can be controlled at one end of the lecture-room during lantern exhibitions. Wires have been brought into the house from the Edison Electric Company's station, and arrangements have been made with that company for furnishing a current when required by lecturers for experiments, and for the lantern. Some new furniture has been purchased and the old repaired.

The back porch has been enclosed, thus affording a passageway from the kitchen to the rear parlor, which greatly facilitates the serving of the lunch. The large table and bookcases have been removed to the library, and a narrow table substituted for serving the lunch.

The desire of the Board has been to make the rooms as comfortable and attractive as possible, and the House Committee has used its best endeavors to carry out their wishes.

GEO. S. WEBSTER, *President.*
For the Board of Directors. L. F. RONDINELLA, *Secretary.*

ANNUAL REPORT OF THE TREASURER.

FOR THE FISCAL YEAR 1895.

Receipts—Cash.

Dues and Initiation Fees:		
1892	$5 00	
1893	5 00	
1894	362 50	
1895	4,805 00	
1896	5 00	
		$5,182 50
Advertisements:		
1894	101 00	
1895	502 00	
		603 00
Proceedings:		
1894	11 75	
1895	76 99	
		88 74
Reprints, 1895		62 75
Interest on Deposits		12 59
Keys		8 00
Total Income		$5,957 58
Cash Balance, Dec. 31, 1894		140 17
		$6,097 75

Expenditures—Cash.

Salaries:		
Secretary	$240 00	
Treasurer	25 00	
Clerks	600 00	
Janitor	240 00	
		$1,105 00
House:		
Rent	1,100 00	
Coal	121 00	
Gas	55 80	
Ice	18 25	
Repairs, supplies, etc.	41 35	
		$1,336 40
House improvement:		
Carpet, furniture, plumbing, upholstering, carpenter work and painting		463 79
Secretary's office:		
Stamped envelopes, stationery, postage and supplies		164 26
Proceedings		903 38
Notices		362 43
Treasurer's office		40 35
Information Committee		142 00
Library		78 40
Luncheons		607 00
Sinking Fund		465 53
Commissions		12 50
Membership Committee		3 00
Safe Deposit Box		5 00
Affidavit of Tellers		2 50
Reprints		16 00
Total Disbursements		$5,707 54
Cash Balance, Dec. 31, 1895		390 21
		$6,097 75

Repectfully submitted,

GEORGE T. GWILLIAM,
Treasurer.

PHILADELPHIA, January 4, 1896.

The undersigned, auditors appointed by the Board of Directors of the Engineers' Club for the fiscal year ending December 31, 1895, certify to the accuracy of the foregoing statement.

MAX LIVINGSTON,
JAMES CHRISTIE,
W. P. DALLET,
} *Auditors.*

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, January 4, 1896.—President George S. Webster in the chair. Sixty-six members and visitors present.

The Tellers reported the election of the following to Active Membership: Messrs. William H. Bixby, William J. Bradley, E. A. Custer, William Easby, Jr., Charles Hewitt and Minford Levis.

Resignations of membership were read, and, upon motion, accepted from the following: Messrs. J. A. Colby, J. H. Covode, Edward H. Jenkins, Charles Lukens, George H. Paddock, Thomas A. Reilly, Robert P. Snowden, C. O. Vandevanter, J. Lindsay Little and J. Sellers Bancroft.

Mr. William C. L. Eglin read the paper of the evening on the "Distribution of Electrical Energy from a Central Station," illustrated by means of a number of diagrams.

Mr. John C. Trautwine, Jr., exhibited a number of lantern-slides illustrative of the Queen Lane division of the city's water-works, with special reference to the repairs recently made on the reservoir.

Annual Meeting, January 18, 1896.—President George S. Webster in the chair. Eighty-seven members and visitors present.

Mr. George S. Webster, retiring President, presented his Annual Address.

The Report of the Board of Directors was presented, and, upon motion, was adopted, with thanks to the Board for its efficient management during the past year.

The Secretary announced the death of active member Mr. John B. Fontaine, on January 6th.

In accordance with Art. VIII, Sec. 1, of the By-Laws, the Treasurer read the names of eighteen members dropped from the rolls for non-payment of two years' indebtedness.

The Committee of Tellers reported that at the election held this date, 162 legal votes were cast, and the President declared the following elected as officers for 1896: President, A. Falkenau; Vice-President, Carl Hering; Treasurer, George T. Gwilliam; Secretary, L. F. Rondinella; Directors, Max Livingston, Joseph T. Richards and L. Y. Schermerhorn.

The new President, Mr. A. Falkenau, took the chair, and made a short and appropriate address, calling attention to the influence of the Club on the development and on the individuality of its members, and the opportunity which it affords for social contact; in the combination of social and scientific purposes, its function is wider than that of the national societies, and of consequently greater personal benefit; the Club has already gained large proportions, and is capable of still greater development if every member will do his share to help as he is able.

Regular Meeting, February 1, 1896.—President A. Falkenau in the chair. Sixty-seven members and visitors present.

In opening the work for the new year, the President made a few suggestions for the consideration of members. He recommended, that members who are acquainted

The first paper of the evening was read by Mr. Thomas G. Janvier, and described with the aid of lantern illustrations, the Sewage Disposal Works at Wayne, Pennsylvania; after the discussion of which, Mr. William Easby, Jr., showed a series of lantern-slides, and gave a brief description of various methods of sewage disposal.

Mr. John C. Trautwine, Jr., described a small experimental filter that had been set up near the Spring Garden pumping station, and called attention to the matter of sedimentation.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

SPECIAL MEETING, January 4, 1896.—Present: President George S. Webster, Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Henry Leffmann, William J. Hoyt, W. C. Furber, C. L. Prince, Edgar Marburg, the Secretary and the Treasurer.

The Secretary reported that Mr. H. C. Lüders, appointed Chairman of the Committee of Auditors, had declined to serve on account of other business, and he was instructed to notify the Alternate, Mr. W. P. Dallett, of his appointment, while Mr. John Birkinbine was appointed new Alternate Auditor.

The Secrtary also reported that two of the Tellers appointed by the Board, Messrs. G. Bacon Price and George M. Sinclair, had declined, and upon motion, the Alternates, Messrs. S. S. Evans and Edwin R. Keller, were made Tellers, and Messrs. John S. Mucklé and R. L. Humphrey were appointed new Alternates.

A circular letter was presented from Mr. Elmer L. Corthell, with an extract from the minutes of the American Society of Civil Engineers, relative to the holding of a series of international congresses of engineers, and the Secretary was instructed to acknowledge the same with a statement that the Board heartily endorsed the action of the Board of Directors of the American Society, as quoted in the extract referred to.

REGULAR MEETING, January 18, 1896.—Present: President George S. Webster, Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Edward K. Landis, C. L. Prince, Edgar Marburg, Henry Leffmann, William J. Hoyt, the Secretary and the Treasurer.

The President reported that, in the place of Mr. John S. Mucklé, who had declined to serve as Teller, he had appointed Mr. Harrison Souder, as there would not have been time to notify him, if his appointment had been made at the Board Meeting. By vote, this action of the President was approved.

The Secretary read a copy of a Bill, to fix the standard of weights and measures by the adoption of the metric system, providing that from the first of July, 1897, the metric system of weights and measures shall be the only one used by all the departments of the United States Government, and also that, from the first of July, 1899, it shall be the only legal system of weights and measures recognized in the United States. After some discussion, it was ordered that this be brought before the Club for action at its next Business Meeting.

The Treasurer's Report for December showed:

REGULAR MEETING, February 15, 1896.—Present: President A. Falkenau, Vice-Presidents John L. Gill, Jr., and Carl Hering, Directors W. C. Furber, Henry Leffmann, Edgar Marburg, Joseph T. Richards, L. Y. Schermerhorn, the Secretary and the Treasurer.

The Treasurer's Report showed:

Balance from December	$390 21	
Received during January	1,839 54	
		$2,229 75
Expended during January		947 89
Balance January 31, 1896		$1,281 86

A letter was read from Mr. Gwilliam, asking the Board to consider the feasibility of placing a telephone in the Club House, and upon motion the House Committee was instructed to obtain information as to cost, etc., and report to the Board.

REGULAR MEETING, March 21, 1896.—Present: President A. Falkenau, Vice-President Carl Hering, Directors W. C. Furber, Henry Leffmann, Edgar Marburg, Max Livingston, Joseph T. Richards, L. Y. Schermerhorn, the Secretary and the Treasurer.

The Treasurer's Report showed:

Balance from January	$1,281 86	
Received during February	482 05	
		$1,763 91
Expended during February		401 26
Balance February 29, 1896		$1,362 65

The Secretary presented a copy of the abstract of the discussion on March 7th, on the filtration of Philadelphia's water supply, that had been sent, on the 10th instant, to six morning and two evening newspapers, and he stated that, as the matter had not been decided in Councils previous to their meeting of March 19th, a marked copy of the printed record was enclosed and mailed to each member of both Chambers, in accordance with the suggestion made at the last Club meeting.

A letter from Mr. Walter G. Berg, suggesting the propriety of The Engineers' Club of Philadelphia taking action in the matter of Senate Bill 1214, "to appropriate funds for investigations and tests of American timber," was read, and the matter explained and discussed, and upon motion the Secretary was instructed to express to Mr. Berg and to Senator Watson C. Squire, who presented the Bill, the strong approval of the Board of Directors of the Engineers' Club of Philadelphia, of continuing the timber-tests inaugurated by the Forestry Division of the United States Department of Agriculture, and its recommendation that a sufficient fund be appropriated by Congress for this purpose, since the results so far obtained by these tests have been of the greatest value in practical engineering work.

The Secretary reported that the Girard Estate, according to newspaper accounts, intended to remodel the entire block between Eleventh and Twelfth and Chestnut and Girard streets, and there was some discussion on the possibility of the Club's having to change its quarters in the future.

The Publication Committee reported that at a recent meeting it was decided to

CONTRIBUTIONS TO THE LIBRARY.

From December 15, 1895, to March 15, 1896.

From Alabama Industrial and Scientific Society.

Proceedings, Volume V, 1895.

From American Institute of Mining Engineers.

Accumulation of Amalgam on Copper Plates;—Bayliss.
Assays of Copper and Copper Matte;—Discussion.
Assay of Silver Sulphides;—Discussion.
Carbon-Bricks in the Blast Furnace;—Raymond.
Corundum of the Appalachian Crystalline Belt;—Lewis.
Cycle of the Plunger-Jig;—Richards.
Effect of Vibration upon the Structure of Wrought Iron;—Discussion.
Effect of Washing with Water upon the Silver Chloride in Roasted Ores.
Folds and Faults in Pennsylvania Anthracite Beds;—Postscript.
Gold Milling in the Black Hills, S. D., and at Grass Valley, Cal.;—Rickard.
Handling of Slags and Mattes at Smelting Works in the Western United States;—Braden.
Kaolin and Clay Deposits of North Carolina;—Homes.
Mineral Resources of Northern Georgia and Western North Carolina;—Blake.
Mining Titles on Spanish Grants in the United States;—Raymond.
Monazite Districts of North and South Carolina;—Mezger.
Ore Deposits of the Australian Broken Hill Consols Mine, Broken Hill, N. S. W.
Phosphates and Marls of Alabama;—Smith.
Present Condition of Gold Mining in the Southern Appalachian States;—Discussion.
Recent Phosphorous Determinations in Steel;—Discussion.
Southern Magnetites;—Discussion.
Specifications for Steel Rails of Heavy Sections Manufactured West of the Alleghenies.
Theory and Practice of Ore Sampling;—Brunton.
Underground Supplies of Potable Waters in the South Atlantic Piedmont Plateau;—Holmes.

From American Society of Mechanical Engineers.

Transactions, Volume XVI, 1895.

From Bureau of Education, Washington, D. C.

Science of Nutrition.

From Canadian Society of Civil Engineers.

Transactions, January to June, 1895.

FROM CITY ENGINEER, LAWRENCE, MASS.

Sixteenth Annual Report, 1893.
Seventeenth Annual Report, 1894.

FROM COMMISSIONER OF EDUCATION, WASHINGTON, D. C.

Report, 1892–93, Volume I.
Report, 1892–93, Volume II.

FROM E. L. CORTHELL.

Lecture Before the National Geographic Society at Washington, D. C.

FROM ELECTRIC RAILWAY GAZETTE.

Electric Car Tests.

FROM B. E. FERNOW.

Timber.

FROM C. E. HOWE CO.

Business Directory, 1896.

FROM INSTITUTION OF CIVIL ENGINEERS, London.

Abstracts of Papers in Foreign Transactions and Periodicals.
Address of Sir Benjamin Baker, President.
Flow of Water;—Bruce.
Jubilee Bridge over the Hooghly;—Robertson.
Light Railways;—Money.
Megass and Refuse Furnaces;—Abell.
Mount Bischoff Tin Mines, Tasmania;—Kayser & Provis.
North Sea and Baltic Canal.
North West Argentine Railway Bridges;—Stuart.
Reconstruction of Barnes Bridge;—Szlumper.
Treatment of Trades Waste;—Naylor.
Weigh Bridges;—Kirby.

FROM LEHIGH UNIVERSITY.

Educational Value of Engineering Studies.

FROM BENJAMIN SMITH LYMAN.

Metallurgical and Other Features of Japanese Swords.
Yardley Fault and Chalfont Fault Rock, So-called.

FROM F. H. NEWELL.

Public Lands and Their Water Supply.

FROM NEW ENGLAND ROADMASTERS' ASSOCIATION.

Proceedings, 1895.

FROM NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

Report of Flameless Explosives Committee, Parts II and III.

FROM S. F. PATTERSON.

Proceedings of the Fifth Annual Convention of the Association of Railway Superintendents of Bridges and Buildings, New Orleans, October, 1895.

FROM STATE AGRICULTURAL COLLEGE, FORT COLLINS, COLORADO.

Seepage or Return Waters from Irrigation.

FROM STATE GEOLOGIST OF NEW JERSEY.

Annual Report, 1894.

FROM TRADES LEAGUE OF PHILADELPHIA.

Proceedings of First Annual Convention of the International Deep Waterways Association, Cleveland, September, 1895.

FROM UNITED STATES GEOLOGICAL SURVEY.

Geologic Atlas of the United States.
Chattanooga Folio;—Tennessee.
Estillville Folio;—Kentucky, Virginia, Tennessee.
Fredericksburg Folio;—Virginia, Maryland.
Harper's Ferry Folio;—Virginia, Maryland, West Virginia.
Kingston Folio;—Tennessee.
Knoxville Folio;—Tennessee, North Carolina.
Production of Chromium and Tungsten in 1894.
Ringgold Folio;—Georgia, Tennessee.
Sewanee Folio;—Tennessee.
Staunton Folio;—Virginia, West Virginia.
Stevenson Folio;—Alabama, Georgia, Tennessee.

FROM UNIVERSITY OF PENNSYLVANIA.

Catalogue, 1895–96.

FROM UNIVERSITY OF WISCONSIN.

Emergencies in Railroad Work;—Loree.

FROM GEORGE S. WEBSTER.

Mechanical Tests of Building Material at the Watertown Arsenal, Mass.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.
INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XIII.] JULY, 1896. [No. 2.

V.

ON CANTILEVER BRIDGES.

BY PROF. EDGAR MARBURG, Active Member of the Club.

Read, April 4, 1896.

THE origin of the word "cantilever" is somewhat obscure.* The term seems to have been first used in architecture to designate a projecting bracket supporting a load. In modern engineering, a cantilever, strictly speaking, denotes a girder fixed at one end and otherwise unsupported. To resist the bending moment at the fixed end, some form of anchorage must be provided. In practice, an anchor arm, or anchor span, usually serves this purpose, in addition to its functions as a simple or non-continuous truss for its own loading. A suspended truss is introduced between the ends of the cantilevers for economical reasons and in order to permit the free deflection of the cantilevers, independently of each other, so that all stresses may remain statically determinate. Common usage has led to the application of the collective term "cantilever bridge" to a structure of which a cantilever proper forms a component part; embracing usually, (*a*) the cantilever arms, (*b*) the anchor arms (or anchor span), and (*c*) the suspended span.

* Cantaliver, cantiliver—probably from the Latin *quanta libra*, of what weight or balance.—*Century Dictionary*.

A cantilever bridge may be then defined as a partially continuous girder, in which the points of contra-flexure are definitely and permanently fixed for all conditions of loading by actually severing the chords at these points. It differs in this important respect from the continuous girder, and further in that the shear can be transmitted across these points of contra-flexure in one direction only, namely *from* the suspended truss *to* the cantilever arms. In properly designed cantilever bridges all stresses are determinable by the ordinary principles of statics.

The construction of cantilever bridges of other than the most primitive kind is of comparatively recent date. The first iron structures of this type were built in 1876, although their advantages under certain conditions had been recognized at an earlier period, and a number of actual designs had been more or less completely elaborated between the years 1860 and 1870. The construction of the steel arch bridge of three 502-foot spans, over the Mississippi at St. Louis (1867-74) deserves mention as an early and notable example of the application of the cantilever principle, during erection by means of a temporary, auxiliary construction.

The first iron cantilever bridge in America was built in 1876, across the Kentucky River gorge, by C. Shaler Smith. It consists of three 375-foot spans, with trusses of the Whipple type, of uniform depth. During the same year (1876) a cantilever bridge of 148-foot span, with polygonal upper chord and single web system, was built in Germany across the Warthe River, near Posen.

During the past fifteen years numerous cantilever bridges have been constructed. The largest of these, that over the Firth of Forth, Scotland, embraces two 1710-foot spans. The Sukhur bridge, over the Indus, and the Memphis bridge, across the Mississippi, follow in the order named, with spans of 820 and 790 feet, respectively.

Among the cantilever bridges recently proposed, the most noteworthy are, the one at Detroit, 1130-foot span; that at New Orleans, 1058-foot span; the Blackwell's Island bridge, including two 850-foot spans, and the six-track Hudson River bridge, at New York, for which the unprecedented span of 2300 feet between centers of towers is contemplated.

mum practicable span for suspension bridges, this limit was placed at 4335 feet for a six-track structure, as "a conservative value of the maximum span, based upon assumptions well within the limits of theory and experience."

In the present paper it is proposed to confine attention more especially to the consideration of the comparative merits of cantilever and non-continuous bridges and to the conditions affecting their relative cost. Certain general matters relating to the economic designing of cantilever bridges will be also presented.

For moderate spans cantilever bridges are, under ordinary conditions, uneconomical compared with non-continuous ones for the following reasons:

First—The trusses of the anchor arms (or anchor spans) are considerably heavier than non-continuous trusses of equal length, owing to (*a*) increased and reversed web stresses from loads on the cantilever arms and suspended span; (*b*) increased and reversed chord stresses from such loading. These effects are relatively much greater in the case of "anchor spans" supporting cantilevers at both extremities than for "anchor arms" sustaining only a single cantilever. The partial or total reversal of stress necessitates the adoption of unit stresses much lower than would be otherwise permissible.

Second—The shore anchorages in cantilever bridges of the Niagara type add materially to their cost, the percentage of increase depending mainly on the disposition of the piers, as determined by local conditions. In the Niagara as well as in the Red Rock bridge the weight of metal in the anchorages was slightly in excess of 5 per cent. of the weight of the entire superstructure.

Considering for the present the question of relative cost only, the disadvantages just cited are neutralized in part by the following favorable features:

First—The combined weight of the trusses in the cantilever arms and the suspended span is less than that of a non-continuous truss equal to their aggregate length.

Second—The cost of erection is less, since usually the greater part of the structure can be erected without false-works.

For moderate spans, a net comparison will show an economic

advantage on the side of the simple trusses, even with an arrangement of piers more favorable to the cantilever system; unless local conditions are such that the construction of false-works would be attended by extraordinary expense.

With increasing spans, certain advantageous features peculiar to the cantilever system become more emphasized, until a limit is reached, which may, perhaps, be placed very loosely at 600 feet,* beyond which favorably conditioned cantilever bridges are more economical than simple trusses resting on the same piers. Before treating this question in more detail, some matters affecting the economic designing of cantilever bridges will be considered.

Theoretic investigations as to the most advantageous location of piers for cantilever bridges possess little value practically. Even were it possible to establish definite conclusions in respect to the least-cost subdivision of the superstructure, a considerable variation in the resulting arrangement would be attended by a relatively small increase of cost, so far as the superstructure alone is concerned. On the other hand, the cost of the substructure is in most cases largely affected by any considerable shifting of the piers. In the case of navigable streams, the location of the channel and the usual least-span requirements give rise to further practical limitations which cannot be disregarded. An examination of existing cantilever bridges will show that the disposition of piers is determined almost invariably, either wholly or in part, by local conditions, irrespective of incidental increase in the cost of the superstructure.

The difficulties underlying a general solution of this problem are, however, by no means confined to the practical considerations just stated. The problem would be sufficiently involved if the investigation were limited simply to the question of least-weight subdivision of the superstructure *per se* for a given number of spans. The analysis would have to be based (*a*) upon an assumed distribution of the moving load, (*b*) a similar assumption for the fixed load, and (*c*) some assumption, whether expressed or implied, in respect to unit stresses.

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* The exact limit will obviously depend on a variety of conditions, such as clear height, as affecting relative saving in masonry and false-works; minimum clear width required; ratio of live to dead load; specifications—especially for reversed stresses, etc.

While no essential error is committed by assuming the live load as uniformly distributed, particularly for spans of considerable length, such an assumption for the dead load is so widely at variance with actual conditions as to practically destroy the value of any conclusions that may be reached. To assume the dead load as uniformly distributed, but of a different intensity for the several principal subdivisions of the bridge, is scarcely less unsatisfactory and is in fact approximately correct only for the suspended span. In the cantilever arms, both shears and bending moments increase rapidly as the pier is approached. This is true also, though to a less degree, for the anchor arm. For the case of an anchor span the error involved by the assumption named is a less serious one. But, furthermore, the relative intensity of dead load upon these several divisions is itself dependent on the relative distances between supports, on the ratio of dead to live load and other circumstances. Any general assumption in advance as to its distribution is therefore unwarranted.

The typical distribution of maximum shears and bending moments over the anchor arm and anchor span is shown in Figs. 1 to 4 inclusive.* In the construction of these diagrams, the following approximate data were used:

ANCHOR ARM (FIGS. 1 AND 2).

RATIOS:	ANCHOR ARM.	CANTILEVER ARM.	SUSPENDED SPAN.
Of Lengths,	2	1	2
Of Dead Load, per foot,	1¾	1½	1

ANCHOR SPAN (FIGS. 3 AND 4).

RATIOS:	ANCHOR SPAN.	CANTILEVER ARM.	SUSPENDED SPAN.
Of Lengths,	3	1	2
Of Dead Load, per foot,	2	1½	1

* The writer is indebted to Mr. F. P. Witmer, Active Member of the Club, for the preparation of the drawings from which the illustrations accompanying this paper were made.

The live load was regarded as uniformly distributed, and of an intensity 2, to the ratio-scale indicated in the tables above. The bending moments and shears from the dead load are plotted as though this loading were also uniformly distributed over each span. An inspection of Figs. 1 and 2 will show that such an

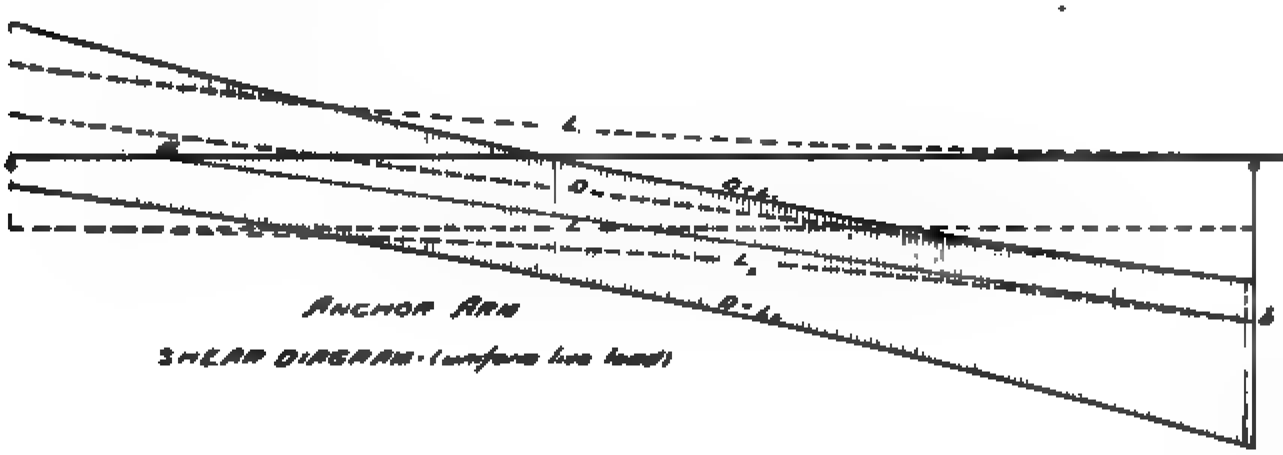


Fig. 1.

D —for dead load.
L'—for live load covering cantilever arms and suspended span.
L_1—for live load on anchor arm, advancing towards left.
L_2—for live load on anchor arm, advancing towards right, combined with *L'*.

Fig 2.

D —for dead load.
L_1—for live load covering anchor arm.
L_2—for live load covering cantilever arm and suspended span.

assumption for the anchor arm is entirely inadmissible. For the anchor span (Figs. 3 and 4) the error is less important, as already stated.

FIG. 3.

D —for dead load.
L^1 —for live load covering cantilever arm and suspended span to the left.
L''—for live load covering cantilever arm and suspended span to the right.
L_1 —for live load on anchor arm, advancing towards left, combined with L'.
L_2 —for live load on anchor arm, advancing towards right, combined with L''.

BENDING MOMENT DIAGRAM-(uniform live load).

FIG. 4.

D —for dead load.
L^1—for live load covering anchor span.
L_2—for live load covering cantilever arms and suspended spans, on both sides.

These diagrams were prepared more especially, however, to exhibit the great range of the reverse stresses, both from shears and bending moments—especially the latter—in the anchor trusses. It is to this circumstance, as has already been pointed

out, that the lack of economy of cantilever bridges, for moderate spans, is chiefly attributable. The maximum variations in the shears and bending moments are represented by the vertical intercepts of the shaded portions of the figures. In modern bridge practice the permissible unit stresses are reduced as the ratio of the ordinates to the upper and lower boundary lines of these shaded figures is increased, especially where these ordinates lie on opposite sides of the horizontal datum line, indicating values alternately positive and negative, for varying positions of the live load. The values of the allowable unit stresses for stresses

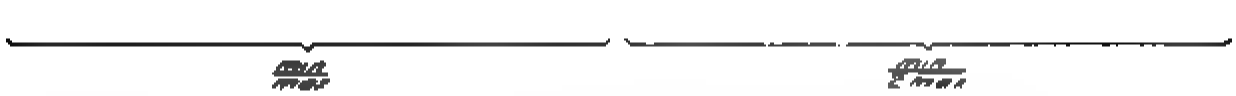


FIG. 5.

both of the same and of opposite characters, according to the usual modern formulas, are represented as ordinates in the accompanying diagram (Fig. 5).

The formulas designated as Launhardt's and Weyrauch's will be recognized as the modified forms of those originally proposed, which have found most general acceptance in American practice. The curves representing the variations of unit stresses, as by Cooper's Specifications, are equilateral hyperbolas. The comparison between Launhardt's and Cooper's formula is correctly shown only for those cases in which the dead-load stress represents the

true minimum. Where Launhardt's formula is specified, the usual requirement is to include the effect of any partial reversal of the dead-load stress, that is, to use the *absolute* minimum stress, in entering the formula. It will be seen from Figs. 1 to 4, inclusive, that this may result in a material decrease of the allowable unit stresses. This decrease is relatively greatest for the main web members in panels containing counters, for which the value of the minimum stress by Launhardt's formula must be placed at zero. This leads to an allowable unit stress of only a (Fig. 5), both for the dead and live load stress, whereas by Cooper's formula no account is taken of the possible reduction of the stress to zero in members not designed to sustain a stress of opposite character.

The ordinates to the curves L_2 in Fig. 1 and L_1 and L_2 in Fig. 3 represent the maximum shears, on the assumption that the live load extends entirely over the cantilever arm and the suspended span, and that a second uniform loading is at the same time placed in the position for maximum shear for the section considered. If this condition of loading be dismissed, by reason of the improbability of its occurrence, and a continuous load be alone considered, then the ordinates to the full line ab (Fig. 1), intersecting L' at the center of the span, will denote the shears for the load covering the anchor arm entirely as well as the cantilever arm and suspended span. In that half of the anchor arm toward the shore end, greater negative shears will then result by assuming the load as covering only the cantilever arm and the suspended span, with no contemporaneous loading on the anchor arm. Such shears are represented in the figure by the ordinates to the horizontal line L'. The lines ab and cd in Fig. 3 have a similar significance to that of $a\,b$ in Fig. 1.

It is to be noted finally that the variations in the values of the shears and bending moments as represented in Figs. 1 to 4, on which the values of the allowable unit stresses are directly dependent, are themselves subject to great variations from changes in the relative length of the anchor trusses, cantilevers and suspended span, and from the ratio of the dead to the live load. It is not possible to properly include all these elements in a theoretic treatment, and if the problem be simplified by introducing

certain assumptions more or less arbitrary, the deductions are of little or no value for practical purposes.

It is therefore held that a reliable determination of the most favorable location of the piers can be made only by considering each case on its own merits. For important bridges, detailed estimates should be prepared for a number of actual designs, as the only safe basis of comparison.

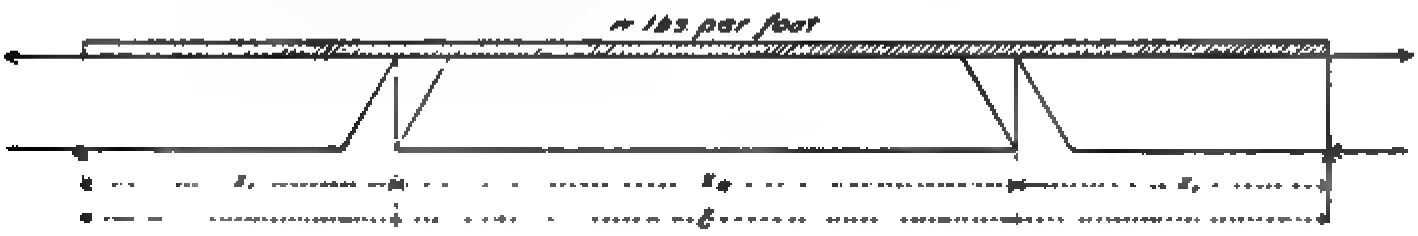


FIG. 6.

A theoretic analysis for establishing the least-weight length-ratio of the suspended span to the total span presents fewer difficulties and is of more general interest, for the reason that the conclusions are only slightly influenced by the relative positions of the piers and further because the most favorable length-ratio can be always adopted without reference to local conditions, as affecting the cost of the substructure.

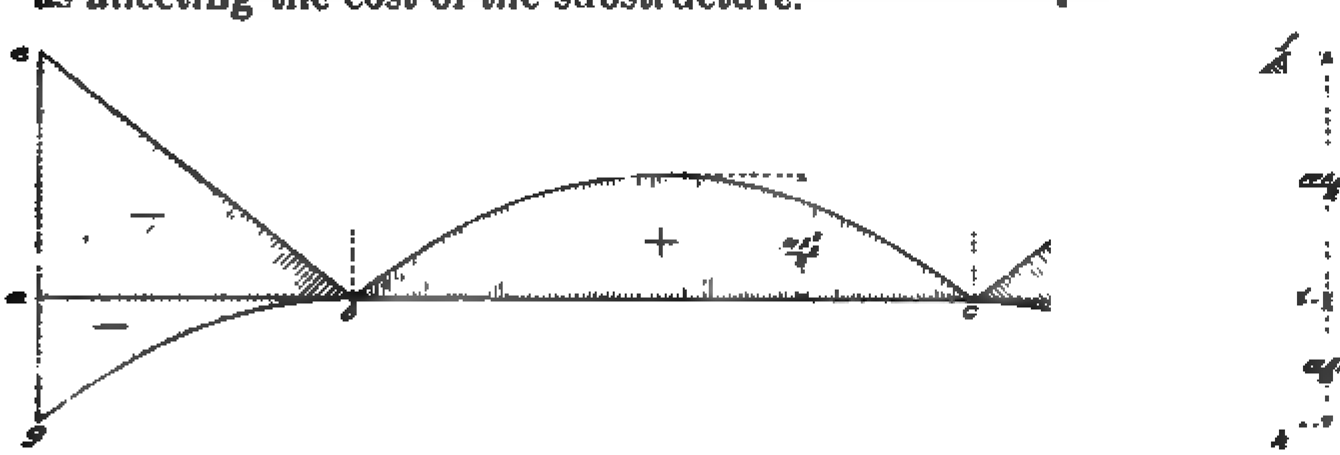


FIG. 6a.

The effect of the live load will be first considered. This load may, with little error, be assumed as uniformly distributed. In fact, for long spans such loading is usually specified, except for the floor-system and secondary members.

Bending Moments (live load).—The bending moments will be maximum throughout with the load extending over the entire span (Fig. 6). Their values are represented by the vertical intercepts in Fig. 6*a*. The curves in this figure are parabolic and

the ordinates to the inclined lines *be* and *cf* denote the bending moments in the cantilever arms from the load on the suspended span. For convenience, these moments, though negative, are laid off above the horizontal datum line.

The average bending moment becomes a minimum for that relation of x_1 and x_2 which reduces the area (Σ M) of the shaded figure to a minimum. With the notation indicated,

$$\Sigma \mathrm{M} = \tfrac{1}{12}\, w x_2^3 + \tfrac{1}{2}\, w x_1^2\, x_2 + \tfrac{1}{3}\, w x_1^3,$$

Placing $x_1 = \frac{1}{2}\,(l - x_2)$,

$$\Sigma \mathrm{M} = \tfrac{1}{24}\, w\, (l^3 - 3\, l\, x_2^2 + 4\, x_2^3). \qquad (1)$$

Equating the first derivative to zero and solving for x_2, there results,

$$x_2 = 0 \text{ or } \tfrac{1}{2}\, l,$$

the former indicating a maximum and the latter a minimum value of Σ M.

In general there may be written $x_2 = z\, l$, the value of z ranging from 0 to 1. Eq. (1) then becomes,

$$\Sigma \mathrm{M} = \tfrac{1}{24}\, w\, l^3\, (1 - 3\, z^2 + 4\, z^3). \qquad (2)$$

Σ M attains its absolute maximum value when $z = 1$, corresponding to the condition of a simple truss of span l.

The average bending moment for any value of the length-ratio z, is found by dividing the resulting value of ΣM from Eq. (2) by the span l. These values for the conditions of maximum and minimum may be tabulated as follows:

CONDITIONS.	z	AVERAGE BENDING MOMENT. $\frac{\Sigma M}{l}$	RATIOS.
Simple truss,	1	$\frac{1}{12}\, wl^2$ (max.)	$2\frac{2}{3}$
Suspended truss = $\frac{1}{2}$ total span,	$\frac{1}{2}$	$\frac{1}{32}\, wl^2$ (min.)	1
Pure cantilever,	0	$\frac{1}{24}\, wl^2$ (max.)	$1\frac{1}{3}$

Shears (live load).—The diagram for maximum shears from a uniform live load is shown in Fig. 7. For the suspended truss the load must be considered as advancing from either end. The

general value of the maximum shear (s_2) in this truss, at any distance x from either end, is expressed by the equation,

$$s_2 = \frac{wx^2}{2x_2},$$

which is the equation of a parabola (Fig. 7) with vertex at b or d.

Denoting the combined areas of the figures $bchg$ and $cdki$ by Σs_2,

$$\Sigma s_2 = 2\int_{\frac{1}{2}x_2}^{x_2} \frac{wx^2}{2x_2}\, dx = \tfrac{7}{24}\ wx_2^2, \qquad (3)$$

If the combined areas of the trapezoids $abgf$ and $delk$ are represented by Σs_1,

$$\Sigma s_1 = \frac{wx_1}{2}(l + x_2.) \qquad (4)$$

From the summation of Eq's (3) and (4), the total area (ΣS) of the shaded portions of Fig. 7 may be written, by placing $x_2 = zl$ as before,

$$\Sigma S = \frac{wl^2}{24}(z^2 + 6)\,. \qquad (5)$$

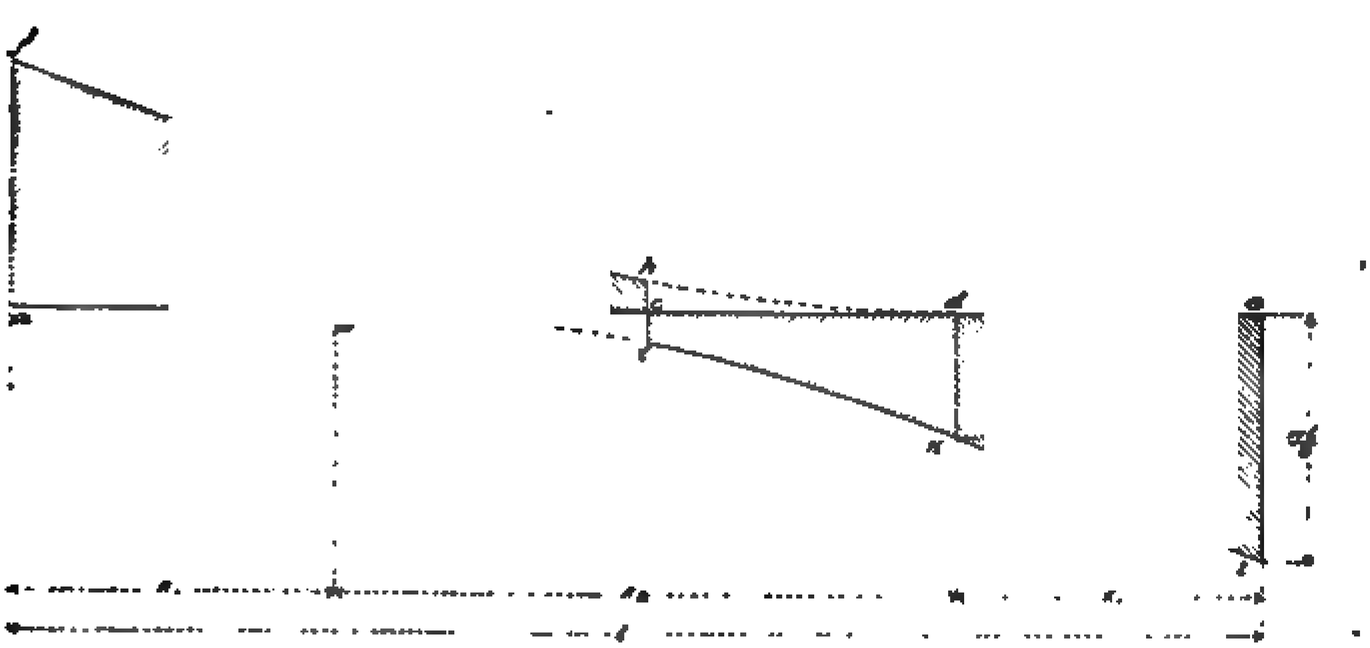


FIG. 7.

It is apparent from this equation that ΣS will be a minimum for $z = 0$ and a maximum for $z = 1$, as is indeed evident from independent considerations.

The values of the average shears for the cases previously considered, may be determined by the aid of Eq. (5) and tabulated as follows:

CONDITIONS.	z	AVERAGE SHEAR, $\frac{\Sigma S}{l}$	RATIOS.
Simple truss,	1	$\frac{7}{24}wl$ (max.)	1.12
Suspended truss = $\frac{1}{2}$ total span,	$\frac{1}{2}$	$\frac{25}{96}wl$	1.00
Pure cantilever,	0	$\frac{1}{4}wl$ (min.)	0.96

In the foregoing, no account has been taken of the countershears, represented in Fig. 7 by ordinates to the curves *bi* and *hd.* Inasmuch as these countershears are relatively small and are neutralized to a considerable though unknown extent—depending on the variable ratio of live to dead load—by the direct shears from the dead load, the resulting error is unimportant. Through the neglect of the countershears, the ratio 1.12 in the

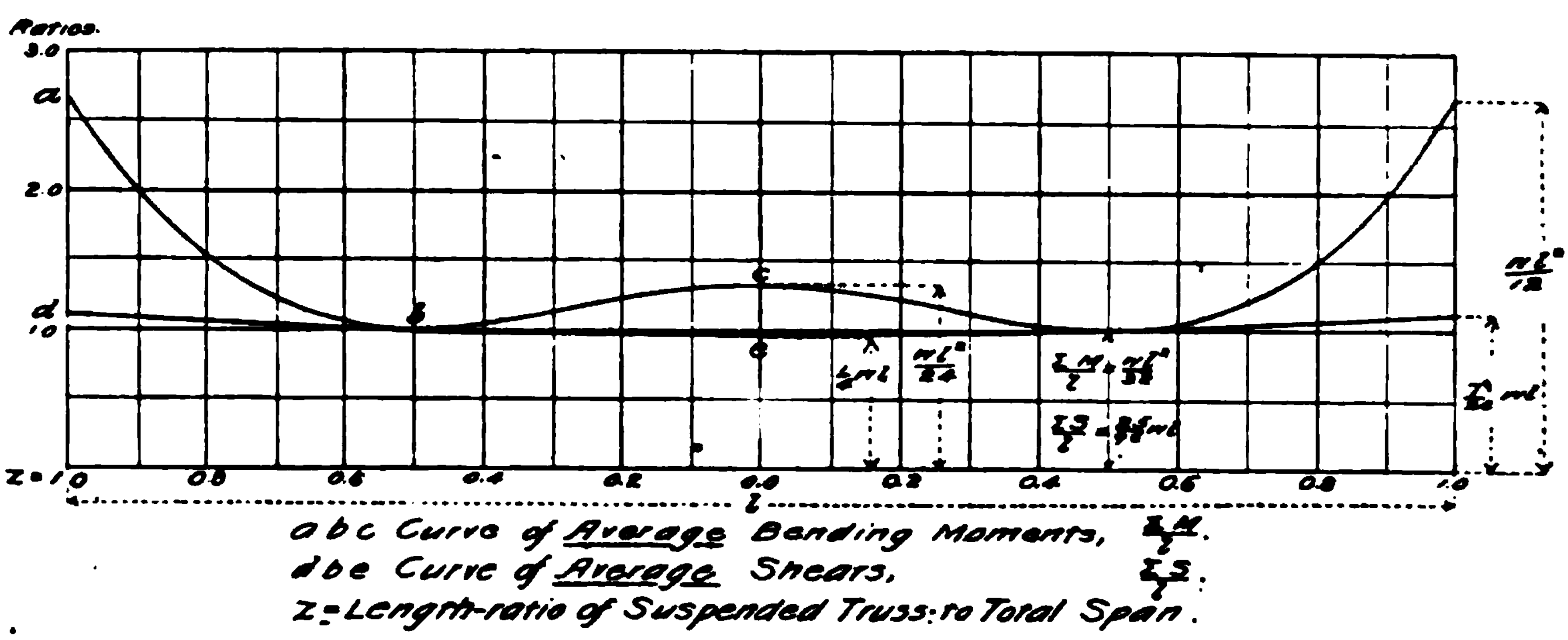


FIG. 8.

above table is slightly less and 0.96 slightly greater than its true value. It should be observed also, that, except in the case of very great spans, the intensity of the assumed uniform live load should be considered as somewhat increased for the direct shears in approaching the center of the span, as well as for the counter shears. This observation applies also to the shears near the free ends of the cantilever arms, especially as the suspended span becomes relatively short. For these several reasons, the ratios of average maximum shears, given in the last column of the table, should be considered only as closely approximate.

The variations in the average bending moment and average shear, for all values of the length-ratio z, are indicated by the ordinates to the curves *abc* and *dbe* respectively (Fig. 8). If it be

assumed provisionally that the dead load is also uniformly distributed, and that ΣM and ΣS include the effects of the dead as well as the live load, the curve *abc* will remain unchanged. The shear curve will, in that case, however, approximate even more nearly to a straight line, since the average shear from a uniform dead load is constant for all values of z. It is seen then, from Fig. 8, that the most favorable length-ratio z is very slightly less than 0.5, so far as the weight of the cantilever arms and suspended trusses are alone concerned, and that no essential increase will result for values of z between the limits of 0.4 and 0.6.

Reverse stresses in anchor trusses.—No treatment deserves to be considered more than loosely approximate which does not include the variations in the bending moments and shears in the anchor trusses, for different values of the length-ratio z, from loads on the cantilevers and suspended span. These moments and shears vary with the uplift that can be exerted on the anchorages, and are, therefore, direct functions of the maximum bending moment (m) at the fixed end of the cantilever.

With the notation in Fig. 6, there may be written,

$$m = \tfrac{1}{2}\, wx_1^2 + \tfrac{1}{2}\, wx_1\, x_2,$$

which for $x_1 = \tfrac{1}{2}\,(l - x_2)$ becomes,

$$m = \tfrac{1}{8}\, w\,(l^2 - x_2^2),$$

or, placing $x_2 = zl$, as before,

$$m = \tfrac{1}{8}\, wl^2\,(1 - z^2). \qquad (6)$$

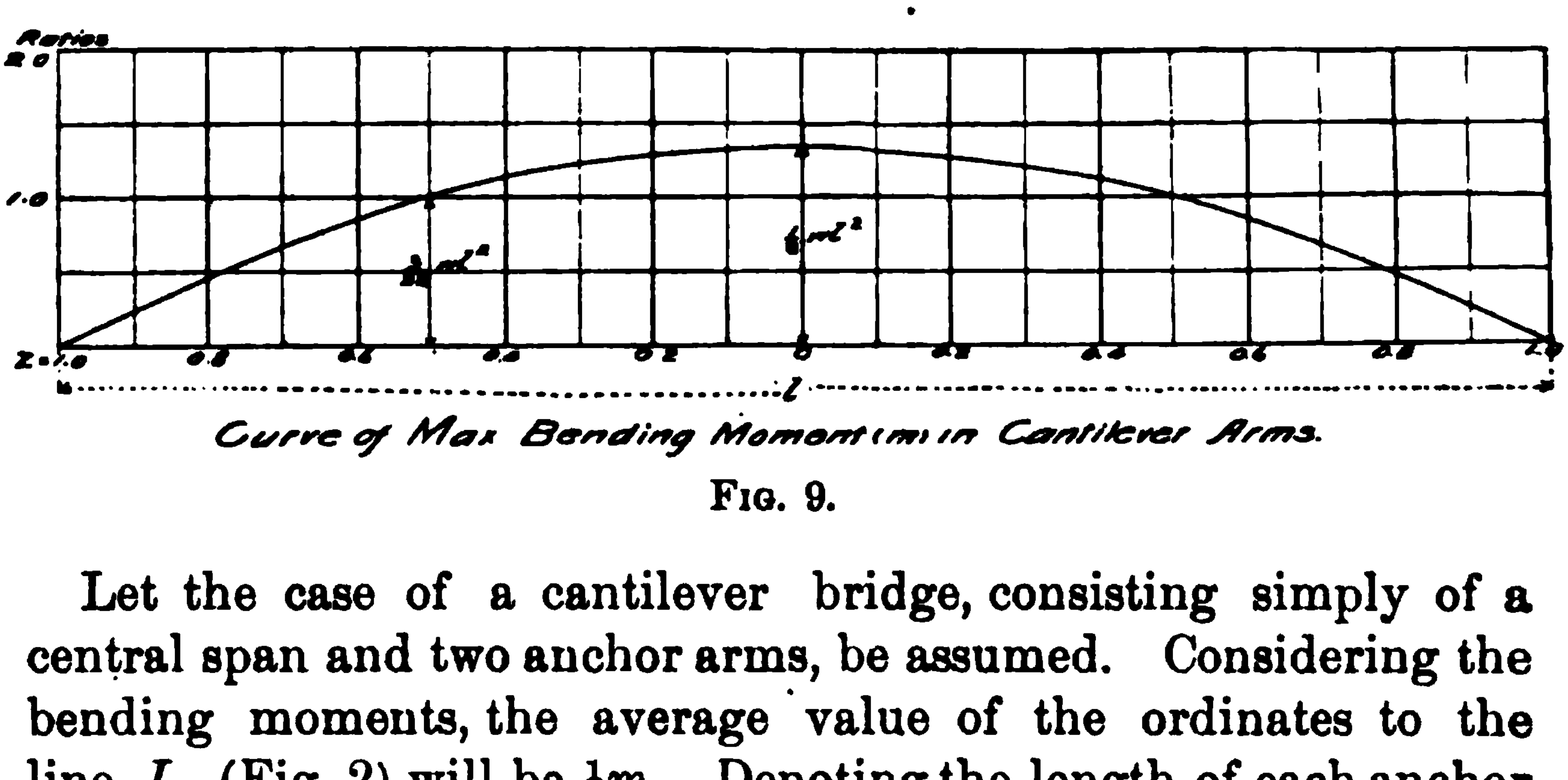
The minimum and maximum values of m occur for $z = 1$ and 0 respectively. The values of m for the conditions previously considered are as follows:

CONDITIONS.	z	MAXIMUM BENDING MOMENT, m.	RATIOS.
Simple truss,	1	0	0.0
Suspended truss $= \frac{1}{2}$ total span,	$\frac{1}{2}$	$\frac{3}{32}\, wl^2$	1.0
Pure cantilever,	0	$\frac{1}{8}\, wl^2$(max.)	$1\frac{1}{3}$

The values of m from Eq. 6, for the entire range of the length-ratios z, are represented in Fig. 9, as ordinates to the curve. It is

to be noted that the vertical scale in this figure is only one-third that used for bending moments in Fig. 8, so that the curvature is relatively much greater than shown. It is seen that the value of m decreases rapidly with the increasing values of z. Considering Fig. 8 in connection with Fig. 9, it appears that the most favorable length-ratio z is necessarily greater than 0.5. Its exact value, in any case, depends partly on the relation of the central span* to the anchor spans, but also largely on the unknown and variable distribution of the dead load, its ratio to the live load, and on the specified unit stresses.

It may be of some interest, though of little value practically, for reasons just stated, to find that value of z which, with a given arrangement of piers, will reduce the average bending moment and shear throughout the entire bridge to a minimum, considering the live load only.



Curve of Max Bending Moment (m) in Cantilever Arms.

FIG. 9.

Let the case of a cantilever bridge, consisting simply of a central span and two anchor arms, be assumed. Considering the bending moments, the average value of the ordinates to the line L_2 (Fig. 2) will be $\frac{1}{2}m$. Denoting the length of each anchor arm by kl, the summation of the negative moments for both arms will give, from Eq. (6),

$$klm = \tfrac{1}{8}\, wkl\ (1 - z^2).$$

Combining this with Eq. (2) and denoting the summation of bending moments for the entire bridge by $\Sigma\, M_1$, there results

$$\Sigma\, M_1 = \tfrac{1}{8}\, wkl^3\ (1 - z^2)\ + \tfrac{1}{24}\, wl^3\ (1 - 3\, z^2 + 4z^3),$$

* The term "central span" is used for brevity in what follows, and is to be understood as including the cantilever arms and the suspended truss.

Advantages of the Cantilever System for Long Spans.

The advantages of the cantilever system, compared with simple trusses for long spans, may be summed up as follows:

(1) *Lower economic depth of trusses.*—It has been shown that the average bending moment is $2\frac{2}{3}$ times as great for a simple truss as for the central span in a cantilever bridge, with a suspended truss of a length equal to one-half the central span, assuming the load as uniformly distributed. Since the shears have been shown to be essentially the same in both cases, it follows that the "average economic depth" of cantilever bridges is considerably less than for simple trusses. For moderate spans this disadvantage of the latter may be in a measure overcome by using a relatively deeper truss. A span-limit is soon reached, however, beyond which an increase of depth requires also a corresponding increase of width, for lateral stability and to provide against the reversal of the lower chord stresses from wind. This leads at once to an increase in the weight of transverse floor-beams, in the dimensions of the piers, and in the case of high piers—the usual condition for long spans—to greatly increased cost of masonry.

(2) *More favorable distribution of the dead load.*—For reasons already stated, the dead load on the cantilever arms increases rapidly as the piers are approached, a condition of loading greatly more favorable than that of a uniform distribution, more particularly in the case of long spans, where the influence of the dead load becomes relatively more important. The effect on the bending moments and shears from an assumed distribution of the dead load, more nearly in accord with actual conditions, will be now briefly considered.

If the suspended truss is of a length equal to one-half the central span, it may be assumed with sufficient accuracy for present purposes that the average dead load per foot on the cantilever arms will be 50 per cent. greater than that on the suspended span.* If further the approximate assumption be made that the

* This agrees well with some of the best recent designs of cantilever bridges, prepared with a view to legitimate economy. The percentage is necessarily variable, however, since, aside from other circumstances, the weight of metal in the floor-system, per foot run, is usually constant for the entire length of bridge.

intensity of the dead load at the free end of the cantilevers is equal to that on the suspended span, and that its rate of increase towards the piers is a uniform one, its distribution will be as shown in Fig. 10.

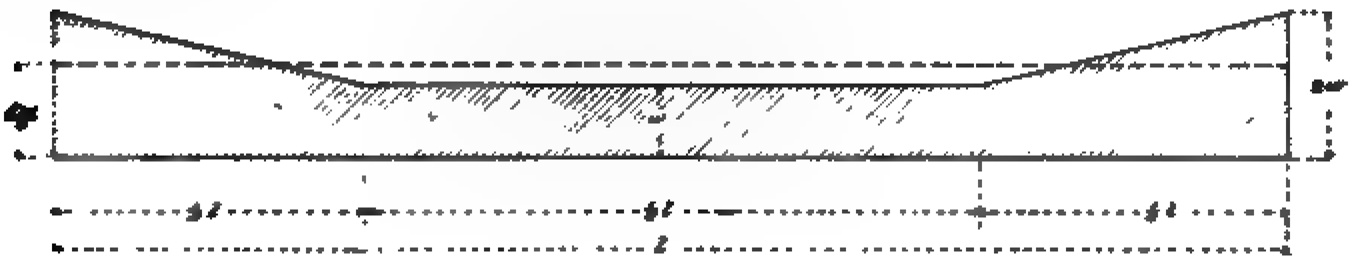


FIG. 10.

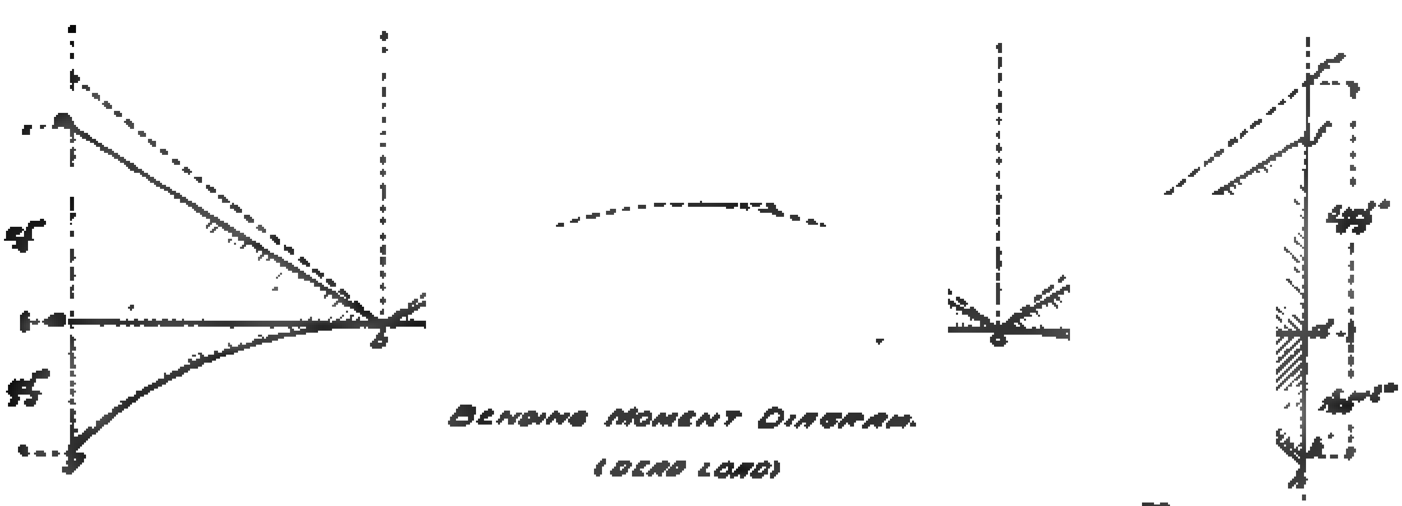


FIG. 10a.

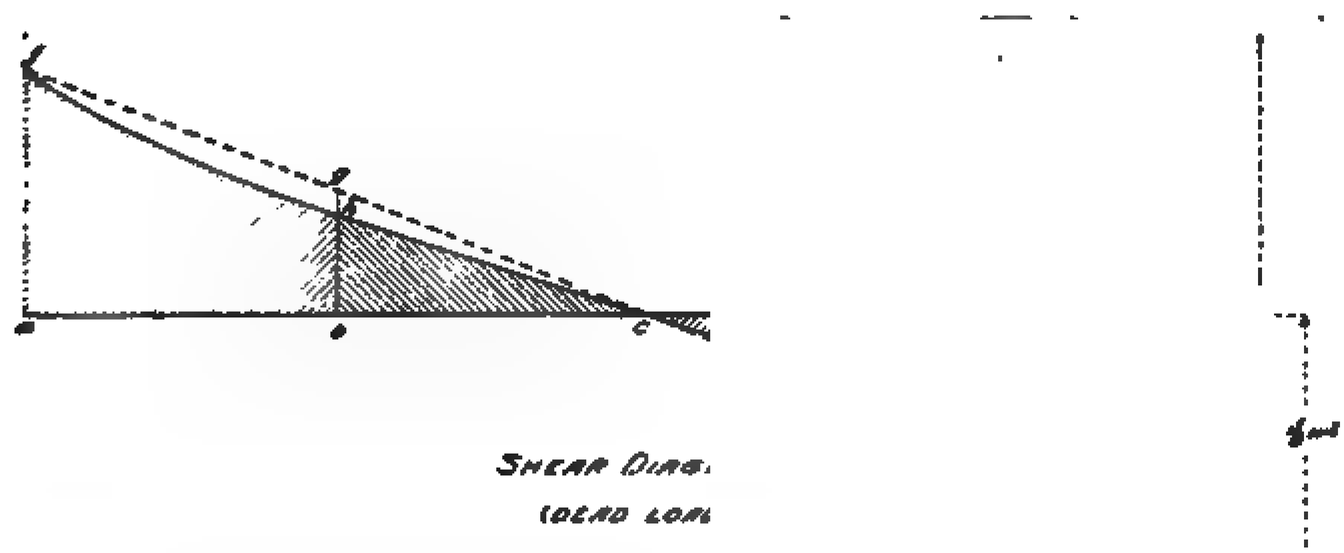


FIG. 10b.

Bending Moments.—To derive a general expression for the bending moments in the cantilever arm, from its own loading, let a section distant z from the free end of the cantilever be considered. If the origin of co-ordinates be taken at this section, the

intensity of loading (w'), at any distance x, towards the free end will have the value,

$$w' = w + \frac{4\,w}{l}\,(z - x),$$

and if the bending moment at the section considered be denoted by m,

$$m = w\int_0^z \left[1 + \frac{4}{l}\,(z - x)\right]\,x\,d\,x,$$

or,

$$m = \tfrac{1}{6}\,w\,z^2\left(3 + \frac{4\,z}{l}\right). \qquad (8)$$

In Fig. 10a these values of m are represented by the ordinates to the curves bg and ch.

The maximum bending moment (m_1), follows from Eq. (8) by placing $z = \frac{1}{4}\,l$, whence,

$$m_1 = \frac{w\,l^2}{24}.$$

By the aid of Eq. (8), the combined area ($\Sigma\,m$) of the figures abg and cdh (Fig. 10a), may be determined as follows:

$$\Sigma\,m = \frac{w}{3}\int_0^{\frac{1}{4}l}\left(3 + \frac{4\,z}{l}\right)z^2\,dz,$$

or,

$$\Sigma\,m = \tfrac{5}{768}\,w\,l^3.$$

The combined area of the triangles abe and cdf is $\frac{wl^3}{64}$, and the area of the parabola bc, $\frac{wl^3}{96}$. Denoting then by ΣM, the total area of the shaded parts of Fig. 10a,

$$\Sigma\text{M} = \tfrac{25}{768}\,wl^3.$$

The *average bending moment* for the entire central span is then,

$$\frac{\Sigma\text{M}}{l} = \tfrac{25}{768}\,wl^2. \qquad (9)$$

The total dead load for the distance l is $\frac{5}{4}wl$, or the mean intensity of loading, $\frac{5}{4}\,w$. If this load were treated as uniformly distributed over the entire central span l, the average bending

moment would have the value found by writing $\frac{5}{4}\,w$ for w in the expression $\frac{1}{32}\,wl^2$ (see table, page 92), *i. e.*,

$$\frac{\Sigma M_1}{l} = \frac{5}{128}\,wl^2. \tag{10}$$

Comparing Eq. (10) with Eq. (9), it is seen that the average bending moment for the central span, on the assumption of a uniform distribution of the dead load, is *one-fifth* greater than that resulting from the distribution shown in Fig. 10, which represents actual conditions much more closely. The bending moments from the equivalent uniform load $\frac{5}{4}w$ are shown in Fig. 10*a* by ordinates to the broken lines.

Shears.—Proceeding in like manner, and with a similar notation, for the shears (Fig. 10*b*),

$$s = w\int_0^z \left[1 + \frac{4}{l}\,(z - x)\right] dx,$$

or,

$$s = wz\left(1 + \frac{2z}{l}\right). \tag{11}$$

The values of s from Eq. (11) are represented in Fig. 10*b* by ordinates from a horizontal line through i to the curve il.

Placing $z = \frac{1}{4}\,l$ in Eq. (11), there results for the maximum shear (s_1), from loading on the cantilever alone,

$$s_1 = \frac{3}{8}\,wl.$$

From Eq. (11) $\Sigma\, s$, for both cantilever arms, may be found as follows:

$$\Sigma\, s = 2w \int_0^{\frac{1}{4}l}\left(1 + \frac{2z}{l}\right) zdz,$$

or,

$$\Sigma\, s = \frac{wl^2}{12}.$$

To this must be added, for the area of bch and cdi (Fig. 10*b*) $\frac{wl^2}{16}$, and for the rectangles ah and ie $\frac{wl^2}{8}$, so that finally,

$$\Sigma S = \frac{13}{48}\,wl^2.$$

The *average shear* for the entire span l is then,

$$\Sigma S = \frac{13}{48}\,wl. \tag{12}$$

Comparing this value with that from an equivalent uniform loading of intensity $\frac{5}{4}w$, as before for the bending moments, the shears from the latter loading will be represented by the ordinates to the broken line fl in Fig. 10*b*, and will have the average value,

$$\frac{\Sigma S_1}{l} = \tfrac{5}{16}wl, \tag{13}$$

i. e., as 15 to 13, compared with the value from Eq. (12), or about *one-sixth* greater.

Uplift.—Finally, the relative uplift on the shore anchorage for the two conditions of loading is shown in Fig. 10*a* by the relative length of the double ordinates $eg = fh$ and $f'h'$, whence it appears that for the equivalent uniform load ($\frac{5}{4}w$), this uplift is *one-eighth* greater than for the load distributed, as in Fig. 10.

(3) *Decreased chord stresses from wind.*—Essentially the same observations apply to the wind stresses as to the stresses from vertical loading. Except for spans of extraordinary length, the trusses are in parallel planes, in which case the chord stresses from wind vary directly as the bending moments. Hence for equal widths, center to center of trusses, the average chord stress from wind for the central span is only *three-eighths* that for a simple truss of equal length, assuming the wind forces as uniformly distributed and of the same intensity in both cases. For the anchor trusses, the average chord stresses from wind exceed those for simple trusses of like span, but since in the former the chord sections required for vertical loading are themselves much greater, little or no increase of section will ordinarily be needed for these wind stresses.

(4) *More favorable distribution of the wind forces.*—Since in cantilever bridges the heaviest construction lies in the vicinity of the piers, the wind pressure upon the structure itself, per foot of length, varies in a somewhat similar manner. It is therefore more favorably disposed, as has been shown for the dead load, than if it were uniformly distributed, as above assumed, and as is approximately true for simple trusses.

(5) *Lower requirements for width, center to center of trusses.*—This follows from the fact that the mean economic depth of truss is lower, and that the average chord stress from wind is

members; (*d*) by providing a rigid system of diagonal and lateral bracing, especially the former; (*e*) by riveting the stringers between the floor-beams and the latter to the posts, and (*f*) by employing, if cost will permit, a solid metallic floor-system, with concrete backing.

DISCUSSION.

Mr. J. Christie.—I would call Prof. Marburg's attention to the fact that he gave no credit to Sedley, an English engineer, who designed cantilever bridges twenty-five or thirty years ago. He was one of the earliest engineers who put them into systematic shape, and, I think, built several bridges. About twenty-five years ago, when the subject of the cantilever became prominent in discussion, it was not infrequently alluded to as the Sedley system. As regards priority, we have to draw the line between continuous girders and the true cantilever. The Kentucky River bridge is sometimes quoted as a cantilever during erection only. Among the early bridges of this type, there is a little bridge in Philadelphia, over the Pennsylvania road, at 40th Street, built during the Centennial year. We might call it a compromise between cantilever and suspension, but it is worthy of a place among the early bridges of that class.

Prof. Marburg.—I did not intend to discuss the question of priority, but of construction only. In regard to the second statement of Mr. Christie, I am not prepared to concede that the Kentucky bridge differs, in any essential respect, from the true cantilever. It will fulfill strictly the requirements of the cantilever bridge of that class.

Frenchman, who in his time has made many different types of burners. One made in 1882 was for burning downward and heating a basket which was below the burner. This basket was made of magnesium threads formed by pressing the paste through a suitable die. This incandescent basket was supported in another made of platinum. He used in this burner what might be called a "regenerative principle," as the air supply to the burner was heated by small flames before it was mixed with the gas for combustion. In order to make the flame burn downward it was apparently necessary to use air under pressure, and as there were many objections to this he made a new burner, in 1883, which was similar to the last, but was not inverted.

E. B. Requa, of Jersey City, endeavored to provide a peculiar-shaped deflector for the air, so that it would come to the burner in such a manner that it would produce the best combustion. He did not use the Bunsen principle at all, but burned all the gas "straight," adding oxygen at the point of combustion.

Sellon, an Englishman, in 1887, used a Bunsen burner with a hood made of platinum and iridium, composed of plates lapped so as to strengthen and hold it in position.

H. J. Bell made his by braiding platinum wire, asbestos cord, or other combustible material, with thread or similar substance, which is then saturated with a solution of rare metals. When subjected to heat the combustible material is consumed, leaving "an incombustible light-emitting network surrounding the incombustible cone."

Among other lamps may be mentioned those of Victor Popp, C. M. Lungren, Eugene Morreau, William J. McNorton, E. B. Cutten, J. N. Pew, J. C. O. Chemin, H. C. Campbell, and O. B. Fahnehjelm.

Several inventors devoted their energies towards making a lamp for use with uncarbureted or fuel gas. These were similar to those already mentioned except that instead of using a Bunsen tube this was omitted. Of this class of lamps may be mentioned those of Alexander Heilbrun, Leonard Henkle and Stewart.

Several attempts have been made to vaporize hydrocarbons, such as gasoline, directly at the burner without the intervention of a machine. This may be done by bringing the liquid to a

down over this and smoothed out to make the stitches even and take out all wrinkles. After it is perfectly smooth, the wire support, which may be of iron and nickel, is placed centrally over the top of the mantle, and the platinum wire is twisted around the ring at the top of the support.

So far we have been dealing with the saturated webs and mantles of cotton, but now we are ready to burn out this cotton and leave a reproduction of it in oxides. To burn out the cotton from the saturated webs, the mantle supports are placed in a block in front of the operator, allowing the mantles to hang naturally. Each mantle is then touched at the top with a Bunsen flame and the cotton is slowly consumed. It is only necessary to touch the mantle once with the flame, as the cotton will burn by itself.

Immediately after burning out the cotton, the oxides are in a very soft condition, and it is necessary to harden them in order to give them the shape that will produce the best results in lighting. This shape should conform as nearly as possible to that of the Bunsen flame, for the flame should just fill the mantle without enveloping it with a thick flame on the outside, that is, if there is too much flame on the outside the radiating power of the mantle becomes very much less, and the candle-power is low.

After being exposed to the flame for some time the mantles become quite hard, and if they are given the proper shape soon after the cotton is burned out, they will retain this shape; so after the cotton is burned out, the operator places the mantle over a soft Bunsen flame, and with a piece of talc gives it the proper shape. The mantles are then mounted on bars where gas is burned in them under pressure, and they are left exposed to a very high temperature until they reach the proper degree of hardness.

At this stage, while the mantles are comparatively hard, they are brittle, and any rough handling will cause them to break, so, in order to render them capable of transportation, they are dipped into a coating which fills up the stitches and fibers and renders the entire mantle one flexible body. The mantles are now trimmed off at the bottom to the proper length, and are packed

DISCUSSION.

THE PRESIDENT.—What is the average duration of the mantles?

MR. BARROWS.—This differs with the different uses to which they are put. If used in churches they will average about one and one-half mantles a year; in residences about two mantles per year; in stores kept open until nine o'clock, three mantles per year; in some stores and factories where there is much dust, about four mantles per year; saloons and places kept open all night will average seven mantles per year. The average life all round is three mantles per year. This is a high average for residences, while two is a very fair average. The greatest life of which we know is something over 20,000 hours' continuous burning. We run them from 3,000 to 6,000 hours before we break them up to look at them. The principal cause of deterioration is dust collecting on the mantle. Sometimes iron scale in the dust of the air is carried up with the air, and is fused by the heat, which will form a red spot on the mantle. In Vienna they recommended a little cap made of pasteboard, to be placed over the chimney when the lamp is not burning, to prevent insects from getting into them. The dust coming up through the air prevents the passage of the gas.

MR. LIVINGSTON.—Why is it that on some evenings the lights burn brightly and on other evenings badly?

MR. BARROWS.—It is probably due to poor gas. It is very hard to tell. The gas pressure will vary to a great extent. We don't find that variation unless there is a variation in the gas.

MR. LIVINGSTON.—How do you explain it when the two burners are on the same chandelier?

MR. BARROWS.—It is probably due to dust in the adjustments. Some of the air shutters are very loose and a jar will cause the air shutter to close or open. Then again very often tar or some other impurity may be carried in the gas and pass more into one burner than into another. By blowing out the fixtures and adjusting the burners the light will probably be the same.

A MEMBER.—Why is it that the light is more reddish than it used to be?

MR. BARROWS.—By varying the fluid we can get a different

light, from a pure white light down to a deep orange. People complained of the pure white light, often thinking it was green, and since then it has been changed very slightly. There is also some difference in the color of the glass chimneys.

MR. S. L. KNEASS.—Is the solution a secret?

MR. BARROWS.—No, the solution may be made of any of the rarer earths.

MR. TRAUTWINE.—What improvement has been made lately? I got a couple of lamps lately which were incomparably better than those I had before.

MR. BARROWS.—The adjustments may be different, or the fixtures may have been blown out. At the start these lights will run from 90 to 100 candle-power, and after running for 500 hours will fall to 60 or 70. The proper adjustment for a Welsbach burner is 2.8 feet. They will average between 90 and 100 candle-power with 2.8. An ordinary five-foot tip will give about 18 candles. I don't know what the candle-power is here in Philadelphia.

PROF. RONDINELLA.—It is supposed to be 16, but it is only between 9 and 10.

PROF. MARBURG.—What is the relative consumption of gas?

MR. BARROWS.—Three candles to the cubic foot. With Welsbach burners, 25 candles to the foot. When burners are sent out from the factory they are marked for different pressures. We have a table showing the pressure of gas in every city. For Philadelphia we use a 75 drill; for a city with high pressure we use an 82 drill, and with low, a 72 drill.

MR. PRINCE.—Ordinarily we get a maximum light in this room when the key is not turned on full. Why is this, if the drill is properly proportioned?

MR. BARROWS.—That is because we do not know the exact pressure at that tap; we only know the average pressure. The pressure varies to a great extent; at one place in Chestnut Hill the pressure in the afternoon at 4 o'clock was 5.5, while in the evening it was only 0.3, a difference of 5.2, which is about two ounces.

PROF. WEBB.—What causes the difference in color?

MR. BARROWS.—One mantle is a little more incandescent than the other.

MR. BOERICKE.—In the German courts the fact was developed that the company did not prepare the mantles in the manner described in the patent.

MR. BARROWS.—The patents did not cover everything that was done, and the patents were not taken out as they might have been.

MR. PRINCE.—I understand that the quality of the light is dependent on the quality of the gas; is this the illuminating or the heating quality?

MR. BARROWS.—The heating quality. You very often notice black spots on the mantles, which show that there is not complete combustion and carbon is condensed on the mantle. By proper adjustment this may all be burned off. We have found that carpet stores are especially hard on mantles, on account of the vibrations. In showing a roll of carpet the salesman drops it on the floor, thus jarring the mantle. We have put in a fixture to counteract vibration, and the lamps have since been burning for some time without a break, where before they would not last for five minutes.

XVI (1895).

THE WATER SUPPLY OF ROME.

By Henry Leffmann, M.D., Active Member of the Club.

Read November 2, 1895.*

Some apology perhaps is needed for bringing before this Club a paper necessarily partaking largely of an archæologic character. I may say that it was written partly to fill a gap in a series of papers as arranged for by the Information Committee, and partly because I think it will not be uninteresting to the Club to hear some account of the engineering work of pre-Christian times, especially on so important a topic as water supply and so interesting a city as ancient Rome.

There is so little of my own work in this contribution that I must begin by setting forth in some detail the sources to which I am indebted. It is mainly to an interesting lecture delivered February 2, 1894, at Cornell University, by Mr. Clemens Herschel of New York City, that I owe the suggestion of this topic, and my knowledge of the work of Sextus Julius Frontinus, who was Water Commissioner of Rome (*Curator Aquarum*) from A. D. 97 to about A. D. 106, just eighteen centuries ago. Mr. Herschel's lecture was published by Cornell University, also in the *Engineering Record*, January 5, 1895, *et seq.* Mr. Trautwine has kindly loaned me a reprint of the lecture. I must acknowledge my obligations to Mr. Prince for preparing most of the lantern slides which I will exhibit to-night, and also to Mr. Herschel for furnishing information as to the editions of Frontinus' work and other interesting matters.

Our knowledge of the water supply of ancient Rome is based almost entirely on this work of Frontinus. Scattered information concerning him shows he was a surveyor in the Roman service, and that he held other offices of a civil and military nature. He was in command at one time in Britain and was Prætor in Rome in A. D. 70. It is not unlikely that the office of Water

* By permission of the Publication Committee this paper was withheld from publication in the January number in order to secure some additional data.

Commissioner, which was one of considerable importance, bestowed upon citizens of distinction, was given him toward the close of his life as a reward for faithful service. Possibly he laid down his arms somewhat in the spirit of the soldier of which Horace speaks.*

His work is entitled *De Aquis Urbis Romæ.* A manuscript of it was found in 1400 by Poggio in the Benedictine Convent at Monte Casino, near Naples; this convent was founded in the sixth century, and the MS., though undoubtedly quite ancient, represents, of course, more than one copying from the original writing. Several other manuscripts are extant, but they are believed to be copies of the one at Monte Casino. There can be no doubt that in the Monte Casino MS. we have the text of Frontinus in substantially the correct form, although there are numerous errors of transcription. Not only does the Latin show the style of his period, but it would be quite unlikely that engineering details of such a character could be originated or described by any Christian monk. The scientific spirit that actuated the people of Rome decayed very rapidly in the years following the first century, and it is indeed fortunate that some denizen of a convent was interested enough in the subject to preserve the text. Latin editions of the work have been quite numerously printed; there are also translations into German and French. There is no complete English edition, though portions of the text have been translated by writers on Roman archæology. Mr. Herschel promises a critical translation which will undoubtedly be very acceptable. The most extended dissertation on the subject is by Lanciani, the well-known Italian archæologist, who contributed to the Royal Academy of the Lynx (in Rome), an extensive paper largely illustrated with drawings of remains of aqueducts and accessory constructions and many copies of inscriptions. This was published as part of the Memoirs of the Academy for the years 1879–80. I have reproduced from this work some of the drawings of the lead pipe and plumbing construction of the ancient city.

Frontinus, after a brief reference to the importance of his task

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* "*Miles ait multo jam fractus membra labore.*"

The nine aqueducts existing in Frontinus' time were in the order of their construction as follows:

Appian	B.	C.	312
Old Anio	"	"	272
Marcian	"	"	145
Tepulan	"	"	126
Julian	"	"	34
Virgin	"	"	20
Alsietinan	A.	D.	10
Claudian	"	"	38
New Anio	"	"	40

The aqueducts made long detours, especially the parts which were underground; the total length of all the channels constructed within four centuries was two hundred and seventy-one miles, of which two hundred and thirty miles were under the surface and forty-one miles carried on sub-structures either arched or not, as required. The idea, therefore, that the Roman aqueducts were all carried on arches, is seen to be far wrong. A picture will be shown giving the shapes of the channels of each aqueduct, and for purposes of comparison the dimensions of the channel of the Marcian may be given: Height, 4 feet 10 inches; width, 2 feet 5 inches; walls, 11½ inches thick. The floors of the conduits are generally broken by inequalities or dips, as if to promote aëration, and catch suspended particles. No methods of filtration, in the sense now given to that term, were in use, but on the other hand waters so pure as to their source, and so free from danger of contamination in their course to the city, would need little treatment. The most objectionable feature was the turbidity of those waters that were gathered from streams, and concerning the new Anio, which is from the river of that name, we are told that an interrupting reservoir was placed just at the point of entrance of the water into the aqueduct. This did not completely fulfill its function, however, during heavy rains. As to the chemical character of the water, we have, of course, no precise information. They were mostly rather hard, and those derived in part, or in whole, from streams, were subject to objectionable turbidity. Frontinus criticises the action of Augustus in building the Alsietinan, which was the seventh in order. "What could have induced Augustus, that most far-seeing of Em-

be one in which a strict limitation will be maintained as to districts devoted to certain purposes. It is unwise that manufacturing establishments should be intermixed with residences, or even that industries of a widely different type should be intermixed; if this idea be carried out, a manifold water supply could be satisfactorily arranged.

We must disabuse our minds of the idea that the Roman engineers did not understand the principle that water will rise to its original level. It has often been said that it was for this reason they constructed the expensively arched aqueducts. In reality, they understood quite well the operation of the so-called inverted syphon. Vitruvius, the well-known writer on architecture, whose work probably dates from the middle of the first century, gives directions for taking levels, and explains the bringing of water in pipes. A large leaden pipe nearly two feet in diameter was found about twenty years ago among Roman ruins. It was encased in brick work, as if the engineer was afraid to trust the lead alone.* The aqueduct construction would doubtless have been much less used if they had been able to make cast-iron pipe of large dimensions. Then, too, we must remember that the methods of destruction in war were far less powerful than at present, and the stout stone arches offered a much greater difficulty to destruction by an enemy occupying the district around Rome than would be the case to-day, when a few hundred pounds of dynamite would be sufficient to interrupt the whole supply of the city. This feature has always seemed to me a matter for consideration in any scheme involving the bringing of water from a great distance by artificial conduits.

Smaller lead pipe was very common; bronze pipe, for attaching to the aqueduct conduits in order to get a continual supply, and also bronze stop-cocks were in use. The lead pipe was made by bending lead sheets to an oval, or rudely circular form, and soldering the joint with pure lead. These pipes were marked, generally, with the name of the plumber, or with the name of the person upon whose property they were placed. From Lanciani's work I have secured engravings of some of these pipes, and copies of these are given herewith. A curious point is that the names of the plumbers are not infrequently those of women, though it

gallons per person; this estimate takes into consideration the stealing of the water, which was a common practice, and occurred perhaps to a greater extent than is indicated in the writings. When we consider this allowance of fifty gallons per head per day, we must recollect that ancient Rome possessed no industries regularly consuming large quantities of water, as do the boilers, dyeing establishments and refineries of to-day. On the other hand, the daily use of water for the baths was large in proportion to the same use in many modern cities. The details of distribution given by Frontinus are set forth by Parker in the tenth volume of his "Archæology of Rome" as follows: There were four classes of recipients: the barracks, the public buildings, the places of entertainment and the public fountains; there were nineteen barrack buildings; ninety-five public buildings; thirty-nine places of amusement, and five hundred and ninety-one open reservoirs or fountains. The latter were under stringent regulations; heavy penalties were imposed for dipping a dirty vessel into the water, and there were laws respecting the control of the overflow. House distribution was not in vogue to the extent which we now see, and this fact doubtless diminished the ruthless waste of water, which is so characteristic of American municipal water supplies.

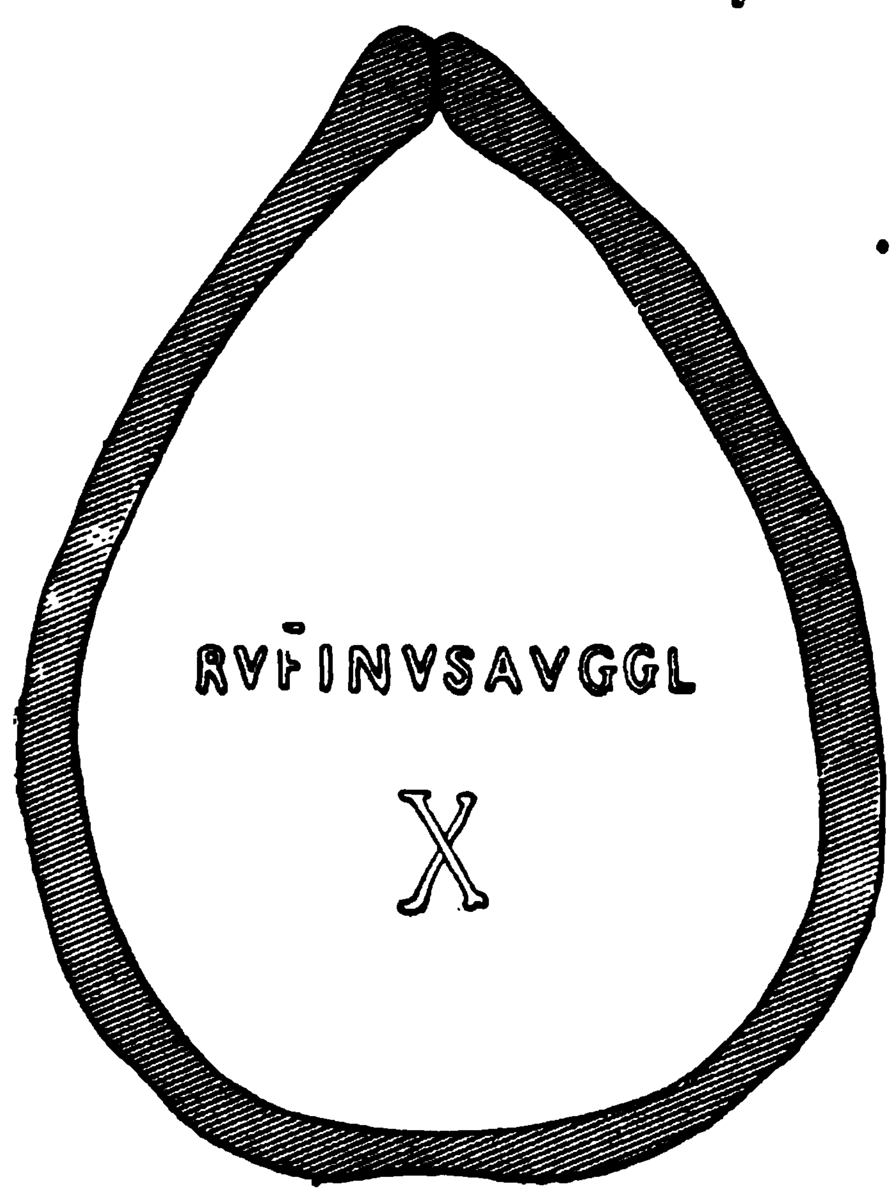
An interesting insight into the abuses of the municipal government of Rome is afforded by some allusions by Frontinus. He seems to have found his office in an unsatisfactory condition, and to have set about reforming the whole administration after the fashion of a conscientious and ambitious engineer. He is justly proud of his profession and especially of the office which he held. After describing the details of nine aqueducts existing in his time, he says: "How can we compare such vast constructions and the importance of such an abundant water supply with the idle pyramids of Egypt or the much vaunted works of the Greeks. Our care," he says, "has not been limited to visiting in person each aqueduct, but we have had models made of each, showing the valleys and rivers crossed; these models have the advantage of showing the constructions, as if we were at the places, and enable us to consider what we ought to do in any case."

Aqueduct building did not cease with the close of the first century of the Christian era; two aqueducts were built later.

the particular city in which we live are so clearly apparent to us every hour of the day, that we unconsciously regard them as worse than at any other time or place. I think, however, that we must not set too high a rating on the character of the Roman government, even in its best period. While the construction of these aqueducts showed a high development of municipal engineering, it seems that many of the details of construction and management were badly carried out. Thus it appears, that the earlier aqueducts fell into decay and newer constructions were made supply the deficiencies of the older ones, yet for several centuries prior to Frontinus' time, no hostile force occupied the territory tributary to the city of Rome. During a large part of this period a standing army, splendidly disciplined, and an Imperial government, with practically unlimited power and the command of any amount of skilled labor at low cost, existed, and there seems, therefore, to have been no excuse but corruption and mismanagement, which permitted these important constructions to fall into decay. We also note the existence of an extensive and persistent system of cheating, by taking water without permission, or taking larger quantities than had been contracted for.

The technical engineering features of the water supply of Rome are discussed quite extensively by Frontinus, but obviously these cannot be presented by me. Fortunately, this is unnecessary, since Mr. Herschel in the lecture above noted has gone fully into the subject and thoroughly elucidated it.

Let us for a moment carry our minds back to the time in which Frontinus wrote,



Section of Pipe made from Sheet-Lead, showing Method of Joining the Edges. The Legends are Imprinted on the Sides of the Pipe.

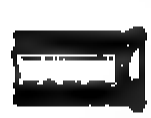
and consider what experiences he may have had. He was born about A. D. 46; in A. D. 63, when Frontinus was nearing manhood, Paul preached in Rome. Curiosity may have led the young patrician, even then, doubtless, exhibiting some of the ambition and intelligence which marked his later years, to hear some of these sermons. The Apostle tells us that the preaching

Section of Pipe made from Sheet-Lead, Showing Method of Joining the Edges. The Legends are Imprinted on the Sides of the Pipe.

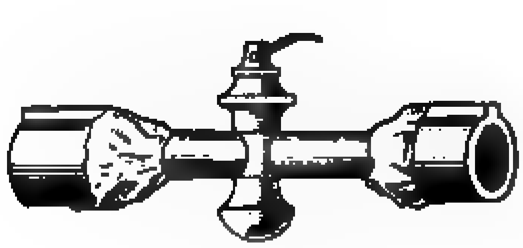
attracted a great number, that some believed the things that were spoken, and some disbelieved. Undoubtedly, if our author was present, he was among the latter.

Frontinus is mentioned several times in the letters of Pliny the Younger, who chose him to be arbitrator in an important case involving considerable property.

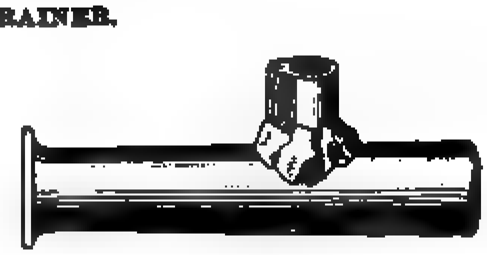
SPECIAL FORM OF LEAD PIPE.



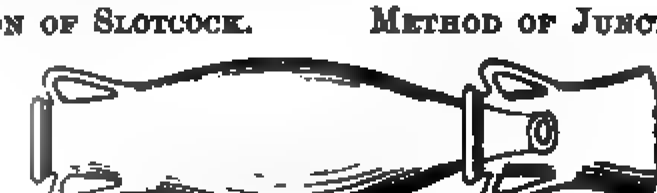
TUBE WITH STRAINER.



INSERTION OF SLOTCOCK.



METHOD OF JUNCTION OF BRANCH.



TUBES MADE OF AMPHORA-LIKE SECTIONS.

TABLE OF EQUIVALENTS.

MILLIMETERS TO FEET AND INCHES.

RUDOLPH BOERICKE, Active Member of the Club.

MM.	0,000	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	MM.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	
0		3— 3.37	6— 6.74	9—10.11	13— 1.48	16— 4.85	19— 8.22	22—11.59	26— 2.96	29— 6.33	32— 9.70	0
50	0— 1.97	3— 5.34	6— 8.71	10— 0.08	13— 3.45	16— 6.82	19—10.19	23— 1.56	26— 4.93	29— 8.30	32—11.67	50
100	0— 3.94	3— 7.31	6—10.68	10— 2.05	13— 5.42	16— 8.79	20— 0.16	23— 3.53	26— 6.90	29—10.27	33— 1.64	100
150	0— 5.90	3— 9.27	7— 0.64	10— 4.01	13— 7.38	16—10.75	20— 2.12	23— 5.49	26— 8.86	30— 0.23	33— 3.60	150
200	0— 7.87	3—11.24	7— 2.61	10— 5.98	13— 9.35	17— 0.72	20— 4.09	23— 7.46	26—10.83	30— 2.20	33— 5.57	200
250	0— 9.84	4— 1.21	7— 4.58	10— 7.95	13—11.32	17— 2.69	20— 6.06	23— 9.43	27— 0.80	30— 4.17	33— 7.54	250
300	0—11.81	4— 3.18	7— 6.55	10— 9.92	14— 1.29	17— 4.66	20— 8.03	23—11.40	27— 2.77	30— 6.14	33— 9.51	300
350	1— 1.78	4— 5.15	7— 8.52	10—11.89	14— 3.26	17— 6.63	20—10.00	24— 1.37	27— 4.74	30— 8.11	33—11.48	350
400	1— 3.75	4— 7.12	7—10.49	11— 1.86	14— 5.23	17— 8.60	20—11.97	24— 3.34	27— 6.71	30—10.08	34— 1.45	400
450	1— 5.72	4— 9.09	8— 0.46	11— 3.83	14— 7.20	17—10.57	21— 1.94	24— 5.31	27— 8.68	31— 0.05	34— 3.42	450
500	1— 7.68	4—11.05	8— 2.42	11— 5.79	14— 9.16	18— 0.53	21— 3.90	24— 7.27	27—10.64	31— 2.01	34— 5.38	500
550	1— 9.65	5— 1.02	8— 4.39	11— 7.76	14—11.13	18— 2.50	21— 5.87	24— 9.24	28— 0.61	31— 3.98	34— 7.35	550
600	1—11.62	5— 2.99	8— 6.36	11— 9.73	15— 1.10	18— 4.47	21— 7.84	24—11.21	28— 2.58	31— 5.95	34— 9.32	600
650	2— 1.59	5— 4.96	8— 8.33	11—11.70	15— 3.07	18— 6.44	21— 9.81	25— 1.18	28— 4.55	31— 7.92	34—11.29	650
700	2— 3.56	5— 6.93	8—10.30	12— 1.67	15— 5.04	18— 8.41	21—11.78	25— 3.15	28— 6.52	31— 9.89	35— 1.26	700
750	2— 5.53	5— 8.90	9— 0.27	12— 3.64	15— 7.01	18—10.38	22— 1.75	25— 5.12	28— 8.49	31—11.86	35— 3.23	750
800	2— 7.50	5—10.87	9— 2.24	12— 5.61	15— 8.98	19— 0.35	22— 3.72	25— 7.09	28—10.46	32— 1.83	35— 5.20	800
850	2— 9.46	6— 0.83	9— 4.20	12— 7.57	15—10.94	19— 2.31	22— 5.68	25— 9.05	29— 0.42	32— 3.79	35— 7.16	850
900	2—11.43	6— 2.80	9— 6.17	12— 9.54	16— 0.91	19— 4.28	22— 7.65	25—11.02	29— 2.39	32— 5.76	35— 9.13	900
950	3— 1.40	6— 4.77	9— 8.14	12—11.51	16— 2.88	19— 6.25	22— 9.62	26— 0.99	29— 4.36	32— 7.73	35—11.10	950

DECIMALS AND FRACTIONS OF AN INCH.

.06 = $\frac{1}{16}$ in.	.12 = $\frac{1}{8}$ in.	.19 = $\frac{3}{16}$ in.	.25 = $\frac{1}{4}$ in.	.31 = $\frac{5}{16}$ in.	.37 = $\frac{3}{8}$ in.	.44 = $\frac{7}{16}$ in.	.50 = $\frac{1}{2}$ in.	.56 = $\frac{9}{16}$ in.	.62 = $\frac{5}{8}$ in.	.69 = $\frac{11}{16}$ in.	.75 = $\frac{3}{4}$ in.	.81 = $\frac{13}{16}$ in.	.87 = $\frac{7}{8}$ in.	.94 = $\frac{15}{16}$ in.

NOTE.—Another table of Equivalents, useful in connection with this, is given in Vol. VII, No. 1, page 19. It gives the values of millimeters from 1 to 100, advancing by single millimeters.

TABLE OF EQUIVALENTS.

KILOGRAMMES PER SQUARE MILLIMETER, IN POUNDS PER SQUARE INCH.

FREDERICK H. LEWIS, Active Member of the Club.

KILOGR. PER SQ. MM.	POUNDS PER SQ. INCH.	KILOGR. PER SQ. MM.	POUNDS PER SQ. INCH.	KILOGR. PER SQ. MM.	POUNDS PER SQ. INCH.
1	1,420	34	48,360	67	95,300
2	2,840	35	49,780	68	96,720
3	4,270	36	51,200	69	98,140
4	5,690	37	52,630	70	99,570
5	7,110	38	54,050	71	100,990
6	8,530	39	55,470	72	102,410
7	9,960	40	56,890	73	103,830
8	11,380	41	58,320	74	105,260
9	12,800	42	59,740	75	106,680
10	14,220	43	61,160	76	108,100
11	15,650	44	62,590	77	109,520
12	17,070	45	64,010	78	110,940
13	18,490	46	65,430	79	112,370
14	19,910	47	66,850	80	113,790
15	21,340	48	68,270	81	115,510
16	22,760	49	69,700	82	116,630
17	24,180	50	71,120	83	118,060
18	25,600	51	72,540	84	119,480
19	27,030	52	73,960	85	120,900
20	28,450	53	75,390	86	122,320
21	29,870	54	76,810	87	123,750
22	31,290	55	78,230	88	125,170
23	32,710	56	79,650	89	126,590
24	34,140	57	81,080	90	128,010
25	35,560	58	82,500	91	129,440
26	36,980	59	83,920	92	130,860
27	38,400	60	85,340	93	132,280
28	39,830	61	86,760	94	133,700
29	41,250	62	88,190	95	135,130
30	42,670	63	89,610	96	136,550
31	44,090	64	91,030	97	137,970
32	45,520	65	92,450	98	139,390
33	46,940	66	93,870	99	140,810
				100	142,240

The figures are correct to the nearest 10 pounds in all cases.

does not amount to one in a thousand. Our commerce with British countries is much more than with all others put together, and therefore the number of men in commerce that would profit by it, is small. Some countries adopted the metric system because they had previously had different provincial systems, and uniformity is clearly a gain. In factories, many new patterns, tools and other appliances would have to be made, with great disarrangement of the present complicated and widespread system of interchangeable parts, at a cost of many millions of dollars. Regarding the ideal beauty, he said that this was limited to the decimal notation, which, however, he considers far from ideally beautiful, believing that an eight-fold notation would agree with the natural and most convenient method of sub-division by successive halving; our present measures would harmonize admirably with such an eight-fold notation, and with slight changes could be made to correspond exactly, if it should be thought desirable; the foot, for instance, might be derived from 27 times successively halving the earth's equator; which is the only standard the earth can give that is not local. In conclusion, he thinks the adoption of the metric system would not only occasion serious permanent inconvenience to the greater part of our population, but would even be an obstacle to perfecting with slight and easy changes, our present essentially far better system.

Mr. Harrison Souder, in a communication, thought it was surprising that a people of so much discernment as the Americans, who had the faculty of finding and using the simplest, quickest and best ways of doing things, should continue to use the old and cumbrous system of weights and measures now in vogue in the United States. He thinks the members of the Club as engineers should try by every means in their power to bring about the adoption of so excellent a system as the metric system is.

In the discussion, the President stated that he was at present building a machine for which he had been furnished with French drawings in the metric system; although he anticipated much trouble he experienced very little, practically none. The men were furnished with metric rules and did the work wonderfully well, with but one or two slight errors; the proportion of errors was less than in similar work where the measurements were in the English system. In a great many ways it facilitated matters.

Mr. John L. Gill, Jr., expressed himself as decidedly in favor of the decimal system; he favored the metric system as far as weights are concerned, but thought the question should be studied before the Club passes any such resolutions. He questioned whether the advantages derived from using the metric system would be as great as some few people imagine they would be.

Mr. John C. Trautwine, Jr., thought if the country would adopt the metric system it would as soon think of going back to the English system as it would of returning to pounds, shillings and pence. It was scarcely a matter for discussion, but more a matter of relative convenience.

Mr. James Christie did not wish to appear as an advocate of the metric system, and thought there were many reasons why it should be considered very seriously. He called attention to the gauge system; it is well known what a great multiplicity of gauge systems there were; three years ago a new gauge was legalized, but he doubts if it is used; such things point to the necessity of some uniform system. He thought it unfortunate that we are not a little more radical in the matter and

Mr. James Christie.—"The movement for its adoption in Great Britain, Canada, and Australia, is now very strong and constantly growing, and the probability is that we will be the last nation to adopt it. There are doubtless some business advantages for shopmen in continuing the present system. I would urge the fact that the use of the metric system is being extended more and more, and this would indicate that it will be universally adopted. I have conversed with those who have used both the metric and the English measurements, and have not heard any of them say that the metric division was inconvenient."

Mr. A. Falkenau.—"We have about completed a large engine from drawings, in which the metric system was used, and repeated by our workmen in the shop. The American workmen fell into line very rapidly, so that we had even fewer errors than is usual on our inch work. The written opposition that we have heard to-night has possibly been based more upon the matter of habit and fear, which might not be realized when this system is adopted. I feared it myself, but have gone through work with it without the slightest trouble, and I therefore personally should not hesitate to adopt it."

Mr. Wilfred Lewis.—"The main objection, which the Messrs. Sellers have against this system, I think, is the expense of making the change. Another feature is the inconvenience of divisions into tenths. In Sellers' shops, however, both systems are used, the injector work being done in millimeters, probably because the original drawings were made in that unit. All taps, dies, and other gauges are based on the inch, and have no equivalent in the metric system. There is probably more manufacturing done to-day in the inch than there is in the meter. On theoretical grounds, I see the convenience of a decimal system, but it is a theoretical convenience and not a practical one."

cussions thereon. Upon motion, the thanks of the Club were tendered to the Committee for its invitation, with sincere hopes for the success of the undertaking.

The following preambles and resolution were presented by the Special Committee appointed at the last meeting of the Club, to report its opinion of what should be the attitude of the Club toward the adoption of a bill presented in the House of Representatives, "to fix the standard of weights and measures by the adoption of the metric system of weights and measures."

WHEREAS, The adoption of an international system of weights and measures is a subject of great practical importance, and

WHEREAS, The continued extension of the metric system indicates that it is the only existing system of weights and measures that bears a promise of universal adoption, and

WHEREAS, The question of the establishment of the metric system is now under consideration by Congress; therefore

Resolved, That the Engineers' Club of Philadelphia respectfully urges its Representatives at Washington to advocate the adoption of the metric system as the only legal standard in the United States, and to promote such international co-operation as will provide unity of practice amongst commercial nations.

A motion to adopt the above was made and duly seconded, and the subject was then discussed. (An abstract of the discussion is given under Notes and Communications.)

On motion it was resolved to decide the question by letter ballot at the next meeting.

The original resolutions were then amended by changing the second preamble and inserting a third so as to read:

WHEREAS, The metric system is the most convenient general system now in use, and its continued extension indicates that it is the only existing system of weights and measures that bears a promise of universal adoption, and

WHEREAS, It is believed that the difficulties in the way of its adoption are far more than compensated by the advantages to be gained by its use,—

The third preamble would then become the fourth, and the resolution is unchanged.

BUSINESS MEETING, May 2, 1896.—President A. Falkenau in the chair. Fifty-six members and visitors present.

Mr. George S. Barrows presented the paper of the evening on "The Welsbach and other Incandescent Gas Lights."

The Tellers reported that 100 votes had been cast *for* the adoption of the preambles and resolution endorsing the metric system as the standard for this country, while 60 votes were cast *against* their adoption. The President, therefore, declared the preambles and resolution adopted by the Club, and upon motion the Secretary was instructed to send copies of the same to each member of Congress from Pennsylvania.

The Board of Directors having devoted considerable time to the consideration of amendments to the revised form of the Charter and By-laws as presented by the Revision Committee, but having not yet been able to complete the amendments which it would propose, upon motion the meeting was adjourned to May 16th, to consider these amendments.

ADJOURNED BUSINESS MEETING, May 16, 1896.—President A. Falkenau in the chair. Thirty-seven members and visitors present.

The meeting was devoted to a discussion of the proposed amendments to the Charter and By-Laws.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, April 18, 1896.—Present: President A. Falkenau, Vice-Presidents John L. Gill, Jr., and Carl Hering, Directors Edgar Marburg, Max Livingston, L. Y. Schermerhorn and the Secretary.

The Treasurer's Report showed:

Amount received in March	$ 428 10	
Balance from February	1,362 65	
		$1,790 75
Expended in March		243 75
Balance March 31st		$1,547 00

The Finance Committee reported bills approved amounting to $632.54, and available good assets of about $4,250.

The Finance Committee asked to have the Patent Office Gazette sent to the Library regularly, and stated that the Society of Arts, London, had sent the Club without charge a number of its Journals to complete our file.

The Information Committee reported the following recommendations with reference to regulations for the future guidance of this and succeeding Committees on Information, and upon motion they were adopted by the Board:

1. The Committee shall prepare and have printed annually a program, giving a complete list of papers for all meetings of the Club, from the first meeting in the fall to the last meeting in February, inclusive.

2. A copy of this program shall be mailed to every member of the Club, together with the usual notice of the first meeting in the fall.

3. The second meeting in December and the second meeting in May shall be devoted to "Topical Discussions," *i. e.*, the formal discussion of important engineering subjects, duly announced in advance of these meetings.

4. At a suitable time in the spring of each year, the Committee shall address a printed circular letter to every member of the Club, inviting proposals of papers and suggestions of subjects for "topical discussions."

5. In arranging the program mentioned in Article 1 the Committee shall endeavor to make suitable provision, as far as practicable, for the diversified interests represented in the membership of the Club.

6. Upon completion of this program the Committee shall address a written communication to every member whose proposal of a paper has been declined, advising him at their discretion of the reasons for its postponement or non-acceptance.

7. The Committee shall encourage the preparation by authors of abstracts of papers for publication in advance of meetings. Such abstracts shall be mailed together with the usual notices of the meetings at which the papers abstracted are to be presented.

8. The Committee shall, on occasion, extend written invitations to Club meetings to such non-members of the Club, more particularly to persons residing in Philadelphia and its vicinity, as may be known to be prominently identified with the subjects to be presented at these meetings. Such persons shall be especially invited to participate in the discussions. To this end the Committee shall furnish the Chair-

bers of the Board since the last meeting, it would be well to make them now, and present them as coming from the Board of Directors.

On motion of Mr. Schermerhorn, duly seconded, it was resolved to insert the words "firm, association, or corporation" after the word "individual" in Article II, Section 6, and to add to that Section the sentence: "This prohibition shall not prevent the Club, upon the request of proper representatives of the city, State, or general government, from naming, upon the recommendation of the Board of Directors, recognized experts in the several professions forming the membership of the Club."

Some further minor amendments were agreed upon.

The Treasurer's Report showed:

Cash received during April	$ 538 42	
Balance from March	1547 00	
		$2085 42
Expended in April		773 64
Balance, April 30th		$1311 78

The Secretary reported that a copy of the preambles and resolution adopted by the Club on the 2d inst., endorsing the metric system as the standard for this country, had been sent to each member of Congress from Pennsylvania, with a letter, and that replies had been received from eight Congressmen promising to vote for the bill or give the Club's opinion careful consideration; from Representative James H. Codding, declining to be guided by the resolutions, and from Senator J. D. Cameron, promising to present the resolutions to the Senate.

A letter was read from Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies, transmitting a copy of a bill now before Congress, providing for the establishment of engineering experiment stations in connection with the colleges established in the several States, and asking for it the careful consideration of the Club. The matter was laid over until the next meeting.

Special Meeting, June 6, 1896.—Present, President A. Falkenau, Vice-Presidents John L. Gill, Jr., and Carl Hering, Directors Henry Leffmann, Edgar Marburg and the Secretary.

The President explained that he had called this meeting at the request of the Publication Committee, to receive from them a report on a new method of publishing the Club's Proceedings. The Publication Committee submitted the report, which was fully discussed by the Directors present, and several changes and additional suggestions were made. The prospective publisher was called in and personally agreed to several of these.

Upon motion, the Board approved of making the contract with the publishers above referred to, in the form as suggested by the Committee, with the latter modifications, and the President and Chairman of the Publication Committee were given power to sign such a contract.

Regular Meeting, June 20, 1896.—Present, President A. Falkenau, Vice-Presidents John L. Gill, Jr., and Carl Hering, Directors Henry Leffmann, Max Livingston and W. C. Furber.

The bill transmitted by Mr. John C. Trautwine, Jr., with his letter of April 29th, which was laid over at the last Board meeting, providing for the establishment of

engineering experiment stations in connection with the colleges established in the several States, was considered, and upon motion, Mr. Trautwine was appointed a Committee of one to report to the Board what action he would consider it desirable for the Club to take.

The Treasurer's report showed:

Balance from April	$1,311 78	
Received during May	189 25	
		$1501 03
Expended during May		282 77
Balance, May 31st		$1,218 26

The House Committee presented an informal report regarding the furniture which it was thought desirable to procure for the Club House, and regarding the admission of members on the evenings of meetings by the presentation of membership cards. It was moved and carried that the Membership Committee be instructed to prepare a suitable form of membership card before the first meeting in September, and $25 was appropriated to pay for the engraving and for printing 500 of them.

Upon motion, duly seconded, the following appropriations were also made to the House Committee:—$11.25 for laying floor-cloth for lunches during the season of 1895 and 1896; $100 for a six-foot settee; $30 for three small chairs; $25 for a writing desk, as recommended by the House Committee; and $50 for necessary incidentals to be spent with the approval of that committee.

CONTRIBUTIONS TO THE LIBRARY.

FROM MARCH 15 TO JUNE 15, 1896.

FROM AMERICAN IRON AND STEEL ASSOCIATION.

Statistics of the American and Foreign Iron Trades for 1895.

FROM BOSTON PUBLIC LIBRARY.

Annual Report, 1895.

FROM BUREAU OF SURVEYS, PHILADELPHIA.

Annual Report, 1895.

FROM CANADIAN SOCIETY OF CIVIL ENGINEERS.

Charter, By-Laws and List of Members, 1896.
Report of Proceedings of Annual Meeting, January 14 and 15, 1896.

FROM CHIEF OF ENGINEERS, UNITED STATES ARMY.

Annual Report, 1895.

FROM COMMISSIONER OF EDUCATION, WASHINGTON, D. C.

Report, 1892–1893, Part 2.

FROM LEON FRANCQ.

La Traction Mecanique des Tramways.

FROM INSTITUTION OF CIVIL ENGINEERS, LONDON.

Abstracts of Papers in Foreign Transactions and Periodicals.
Centrifugal Fans;—Heenan and Gilbert.
Chicago Conference on Aerial Navigation;—Pole.
City and South London Railway;—Greathead.
Efficiency of Gas-Producers;—Jenkins.
Low-Level Bridges in Queensland;—Brady.
Physical Properties of Iron and Steel;—Arnold and Wrightson.
Supporting Powers of Piles;—Kreuter.

FROM E. H. KEATING.

The Water Supply of the City of Toronto, Canada.

FROM J. KENNEDY.

Annual Report of the Harbor Commissioners of Montreal, 1895.

FROM HENRY LEFFMANN.

Appeal of the Quaker City Elevated Railroad Company.
Hand-Book of the Lower Delaware River, 1895.

FROM H. M. NORRIS.

Digest of Physical Tests and Laboratory Practice, April, 1896.

FROM PATENT OFFICE, LONDON.

Patents for Inventions, Abridgments of Specifications:
Acids, Alkalies, Oxides and Salts, Inorganic, Class 1.
Aeronautics, Class 4.
Chains, Chain Cables, Shackles and Swivels, Class 24.
Electricity, Conducting and Insulating, Class 36.
Electricity, Measuring and Testing, Class 37.
Fish and Fishing, Class 48.
Fuel, Manufacture of, Class 50.
Gas Manufacture, Class 55.
Hats and Other Head Coverings, Class 63.
Labels, Badges, Coins, Tokens and Tickets, Class 73.
Lace-Making, Knitting, Netting, Braiding and Plaiting, Class 74.
Life-Saving (Marine) and Swimming and Bathing Appliances, Class 77.
Non-Metallic Elements, Class 96.
Sewing and Embroidering, Class 112.
Ships, Boats and Rafts, Division I, Class 113.
Small Arms, Class 119.
Starch, Gum, Size, Glue and Other Stiffening and Adhesive Materials, Class 121.
Sugar, Class 127.
Tea, Coffee, Cocoa and Like Beverages, Class 129.
Toys, Games and Exercises, Class 132.
Umbrellas, Parasols and Walking Sticks, Class 134.
Watches, Clocks and Other Time-Keepers, Class 139.

FROM SPANISH LEGATION, WASHINGTON.

Spanish Rule in Cuba.

FROM STATE GEOLOGIST OF NEW JERSEY.

Annual Report, 1895.

FROM STATE GEOLOGIST, PENNSYLVANIA.

Atlas to Report F 3.
Index Volume.
Summary Final Report, Vol. 3, Part I, Carboniferous; Part II, Carboniferous, New Red.

FROM UNITED STATES COAST AND GEODETIC SURVEY.

Bulletin No. 35, Alaska.

FROM UNIVERSITY OF MINNESOTA.

Engineers' Year Book, 1896.

FROM UNIVERSITY OF WISCONSIN.

Electrical Engineering in Modern Central Stations;—Ferguson.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.
INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XIII.] NOVEMBER, 1896. [No. 3.

VII.

THE ELECTRIC STORAGE BATTERY.

By RUDOLPH H. KLAUDER, Active Member of the Club.

Read June 6, 1896.

THE purpose of this paper is to call the attention of the members of this Club to the dawning of what the writer confidently predicts to be a new era in electrical station practice in this country. The evidences of this dawning are on all sides of us, and a few cases in point will be hereinafter referred to in detail. The time has at last gone by, when it was at least safe for a central station manager to "decide" offhand and in ignorance, that his plant did not need a battery, and to say that it was not a legitimate piece of apparatus, that it was unreliable, and unrivalled in its money-consuming ability.

The man who is keeping up with the progress of events can now no more consistently refuse to consider the advantages of accumulators than of condensers, for the particular set of conditions under which he is working. An efficient, durable storage battery, which is in every sense commercial, is obtainable, and has as much right to receive consideration with reference to its ability to meet the requirements of the case, as any other piece of apparatus which may be older or better known.

The natural question is, what is producing this storage battery renascence? The electrical accumulator is not a new piece of apparatus. What is the occasion of this general renewed interest in it?

Before proceeding further it seems well to state that the situation in this country is curiously at variance with that in Europe. In Germany, for instance, it is actually the exception to find a large direct current station without its battery; and the company manufacturing the Tudor battery there have installed over 5,000 isolated plants, and 15 railway plants. Of all the central stations in Germany and Austria, 80 per cent. are equipped with storage batteries. In France the company making the Chloride accumulator turns out several tons of plates a day. In England the application has been principally to small, isolated plants, but there are several thousand of these, and it seems to be only the comparative fewness of large central stations that limits the extension of the battery field in this direction. Very large central stations have recently been installed by a company at Manchester, London and Belfast, and there are more then twenty central stations using accumulators throughout the United Kingdom. That company claims to have sold a number of cells which would, in a continuous row, reach six miles. It is not improbable that the predominance of direct current stations over those using the alternating current throughout Europe is due to the advantages in the use of the accumulator, and conversely the fact that the high voltage alterternating-current type of station is so common here has been one obstacle to the more extended use of batteries in this country.

In order to set forth the principal answer to the question asked in the introduction, it may be well to glance at the fundamental reasons underlying the former stagnated condition of the electric storage battery industry in this country. One of these was undoubtedly an unfortunate condition of protracted and profitless litigation into which the manufacturing companies were drawn by the patent situation. We need not, even if it were possible, enter into the details of this entanglement, but it will be sufficient to say that the Gordian knot has at last been cut by the strongest of these companies, by the heroic expedient of " buying

fication of the latter type resulted in a very important plate known as the "chloride," from the method of its production, into the details of which it is not necessary to enter here. It has been one of the most successful in practical use, and the negative plate thus produced is, without doubt, the best one thus far obtainable. In combination with a properly selected positive, depending on the work to be done, it is in a large majority of the plants in this country to-day. Its principal value lies in its ability to maintain its capacity at high rates of discharge. This has been a desideratum long sought after by the experimenters, and is one that may be said to be essential to the proper utilization of the electrical accumulator in central station work, where its great value as a regulator and reservoir, depends on its ability to meet the sudden fluctuations of the load by short but heavy discharges.

The only other plate that need now be touched upon is the "Tudor" plate. This is of German origin, and is a grooved plate that was originally pasted, but is now formed entirely electrolytically, in deference to the reaction to the Planté principle, and is the German solution of the problem of the production of a plate adapted to the heavy work met with in central station practice.

It will now be well to consider some of the practical uses that can be made of the storage battery in generating plants. For the purpose of a classification these may be enumerated as follows:

First—To take the "peak" of the maximum load.

Second—To take the entire minimum load.

Third—To act as an equalizer or reservoir.

Fourth—For the equipment of annex stations.*

By the "peak" of the maximum load is meant that high rise observable in the load curve of every lighting and power station that occurs during the evening of every day. In the load of city trolley stations there is a morning as well as an evening peak, but the former is usually not so well marked, being broader and

* The writer is indebted for this classification to a paper by C. L. Edger, on "Practical Experience with Storage Batteries in Central Stations," read before the American Institute of E. E., November 20, 1895.

ble degree of security against interruption of his service. In absolutely no other way can the emergency of either a disablement of a part or the whole of the machinery, or an excessive overloading of the same, be met. Under these circumstances the battery is prepared for a limited period to discharge at any rate that may be necessary, and no hint whatever of the confusion that may be reigning at the station, is obtainable from the lights or the motors that are being supplied.

It is in its application during the day as a reservoir or equalizer that the battery will usually, in actual station work, obtain the necessary charging. This occurs in the following way: As the load on a station increases, one unit after another is started up; each one, as it is thrown in, being called upon for but a small portion of its capacity. Under these conditions it is working very inefficiently, and could we to advantage utilize its entire output we might obtain the same without proportionately increasing its drain on the boiler. Now, by allowing the battery to charge at these periods, we are enabled to do this and to keep every generator in use, constantly at nearly its maximum capacity. In doing this we need also have no fear of not being able to meet any sudden increase in the load, as the battery will, should occasion require, respond to any degree for a limited time, and prevent any drop in the voltage. Here again does the battery relieve the mind of the station manager of an incubus. In spite of every precaution, in spite of having every piece of apparatus constantly in first-class shape, in spite of holding every man always on the *qui vive*,—cases will occur where the weight of circumstances is too great, and the pressure on the system falls below a reasonable minimum. An interruption is the only thing worse than this in the eyes of a station manager. And now by having an accumulator auxiliary, this is rendered absolutely impossible. Boiler, engines, and dynamos have been sacrificed to obtain what the battery will furnish quietly, automatically and surely.

This regulating function of the accumulator has also an especial value in isolated private plants, in which gas engines are the usual source of power. It is a fact that twice the number of 16 c. p. lights can be gotten from a given amount of gas utilized in

driving an engine and dynamo than would be obtained by burning the gas directly. At the same time it is impossible to obtain a gas engine that will maintain an approximately uniform speed under variable load, or a load a little below its maximum; the efficiency of a gas engine also falls off very rapidly as we lessen its load. Here a storage battery connected in parallel with the generators will prevent absolutely the fluctuations in the voltage due to the variable speed, and by taking its charge will serve to bring the engine load up to its proper figure. The battery thus connected to a generator running at a variable speed may be alternately charging and ceasing to charge with each explosion, and no indication of the fact can be gotten from the lamps. This function of a battery is also of especial value in electric elevator work, where, by taking the strain of the heavy starting load from the generator, it allows us to reduce the capacity of the latter to a fraction of what would otherwise be necessary. From this reduction in the cost of the installation the electric elevator is enabled to compete in cost with the hydraulic. For this purpose the battery is simply connected in parallel with the generator and is charged at periods of light load. On the starting of a car, the heavy outflow of current comes mainly from the battery and the generator continues running without overloading. The action is entirely automatic.

By the application of the electric storage battery to the equipment of annex stations, we are enabled to obtain a great advantage in the handling of the business of a large area, such as a city. It enables us to concentrate our generating plant at some advantageous point where water for condensing can be obtained, and where the cost of handling the coal and ashes will be a minimum, and to connect it by a radiating system of conductors with a number of outlying stations. These stations contain the batteries, each supplying the district immediately surrounding it. The generating machinery and the copper in the tie lines need not be calculated for the maximum load, but only for this minus the part carried by the batteries. The batteries are charged during periods of light load, and whenever there is power to spare for the purpose; at the maximum hours the outlying stations would discharge in parallel with the central.

Having classified and considered the various directions in which the electric storage battery is capable of being advantageously applied in generating plants, it will now be well to enter more fully into the theoretical laws governing these applications. A consideration of these laws is necessary in each particular case to determine the most thorough manner in which the problem that is presented may be solved by the aid of accumulators. Of course, as a basis of the whole question, there is the fact that the load on a station is never constant, and usually varies between wide limits. There is in particular the "peak" before referred to—the evening load—which is frequently from seven to ten times the minimum load. The efforts of station managers have been constantly directed towards lowering and broadening this peak. Inducements have been made to customers to use the current during other hours of the day for power, heat, etc.; while the use at these hours of maximum demand has been in some degree discouraged. As, however, the peak is the result of certain conditions quite beyond control, these efforts have been, we may say, totally abortive. It is obvious that the only solution is some method of storage.

This variation in the load, of course, introduces the difficulty of having the generating machinery running at a fraction of its capacity, and consequently inefficiently. In practice this difficulty is lessened by the division of the generating plant into several units of various capacities, the object being that such a combination of units may be run as will be able to carry any load likely to occur with tolerable efficiency. Practically this object is only partially obtained, and it is found impossible to avoid the constant running of machinery at a fraction of its normal output, and consequently with a very low efficiency. On the other hand it has been found possible at the Boston Edison station, where batteries are used, to avoid ever running a unit under a load less than 75 per cent. of its capacity.

Besides this difficulty due to the irregularity of the load, there is the corresponding one of having a large part of the generating machinery lying idle most of the time. Machinery must be installed in a station to take care of the maximum demand, and the investment thus made would be adequate for maintaining this

maximum during the whole twenty-four hours. As no market can be found for this current during the greater part of the day, the burden of earning interest on the whole investment is thrown on a portion of the machinery installed. A fraction expressing this fact, has received the name of "load factor," and is the ratio of the mean load on the station for a given length of time, as for example a day, to the maximum load, or in other words, it is the proportion that is utilized of the total earning capacity of the station.

The problem will be in any particular case, to determine what the cost will be of producing the power with and without the use of a battery. The data of the problem are best and most con-

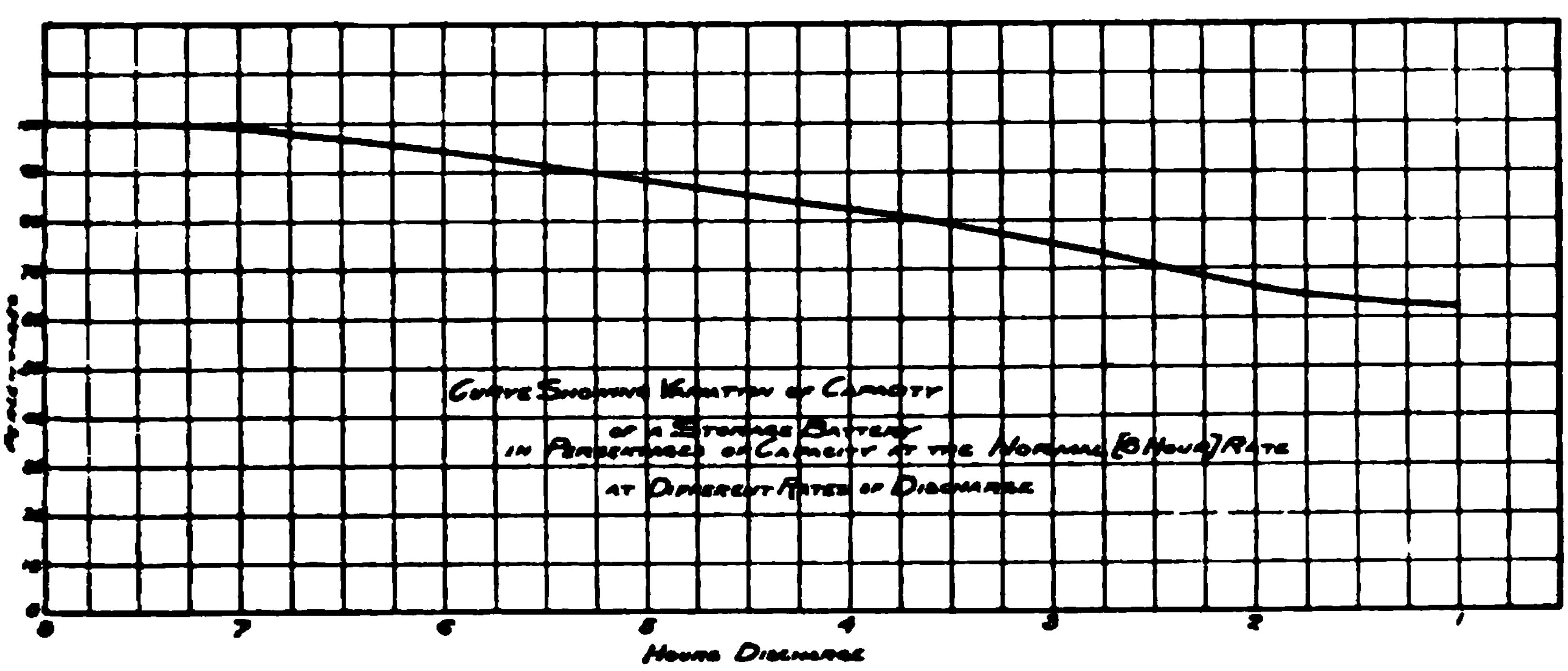


FIG. 1.—CURVE SHOWING THE VARIATION OF THE CAPACITY FOR VARIOUS RATES.

veniently furnished in the curve representing the station's daily load. The extent to which accumulators may be applied will depend solely on the form of this curve. There are two quantities to be first determined from it, and upon these will depend the capacity of the battery required. These quantities are the "rate" and the "capacity" of the battery. By the "rate" of the battery is meant the maximum output in amperes that under ordinary circumstances will be required of the battery; and by the "capacity" is meant the maximum total discharge in ampere-hours that the battery must furnish in an ordinary day. These two factors are related to each other by the inherent properties of the accumulators themselves. The curve, Fig. 1, shows the variation of capacity of an accumulator in its percentage of the normal,

for various rates of discharge, the eight hour rate being taken as normal for this type. The facts represented by this curve are, as has been stated, the result of a recent achievement in storage battery manufacturing, and have done more, perhaps, than any other one thing to give an impetus to the popularity of the apparatus. It is not more than a year ago that battery manufacturers hesitated to allow anything in the nature of an excessive discharge, and in fact such usage could result only in a great loss in efficiency for the battery, and in rapid deterioration. The normal rate was usually taken at ten hours, that is, the current in amperes at the normal rate was one-tenth of the capacity of the cell in ampere-hours. Only those who have had experience in coping with the difficulties in introducing the use of batteries, can appreciate what it means to have a cell whose manufacturers will allow a one hour discharge rate, and whose capacity at that rate is 50 per cent. of the normal.

It is this curve that will furnish us with the necessary relation between the "rate" and the "capacity." In examining and comparing the curves from lighting and railway power stations, a marked difference is to be noted between them. While in both there is the same variation of load for different hours of the day, and in both the same momentary fluctuations due to the sudden switching on and off of lights and the stopping and starting of motors, we are struck by the fact that these variations and fluctuations bear an opposite relation to each other in the two cases. In railway work the momentary fluctuation due to the stopping and starting of cars, and to the changes in grade and speed, are very large as compared with the variations from hour to hour, due to an increase or decrease in the number of cars in service, and their heavier or lighter loading. In the load of a lighting station on the other hand, while the momentary fluctuations are slight, the variations, as exemplified by the oft-mentioned peak, are immense. The result of this is, that in attacking our problem in the two cases, we find it necessary to give the "rate" of the battery greater proportionate consideration in power work, while in lighting, the "capacity" will usually be the governing factor.

For the purpose of illustrating the method of attacking a problem of this sort, the curve, Fig. 2, is taken. This curve repre-

sents the load in amperes of a central station in this city, and may be taken as typical of the load curves of stations of its class. That which at once strikes us as its prominent feature is the ever-present peak. This in the present case reaches a maximum of 18,800

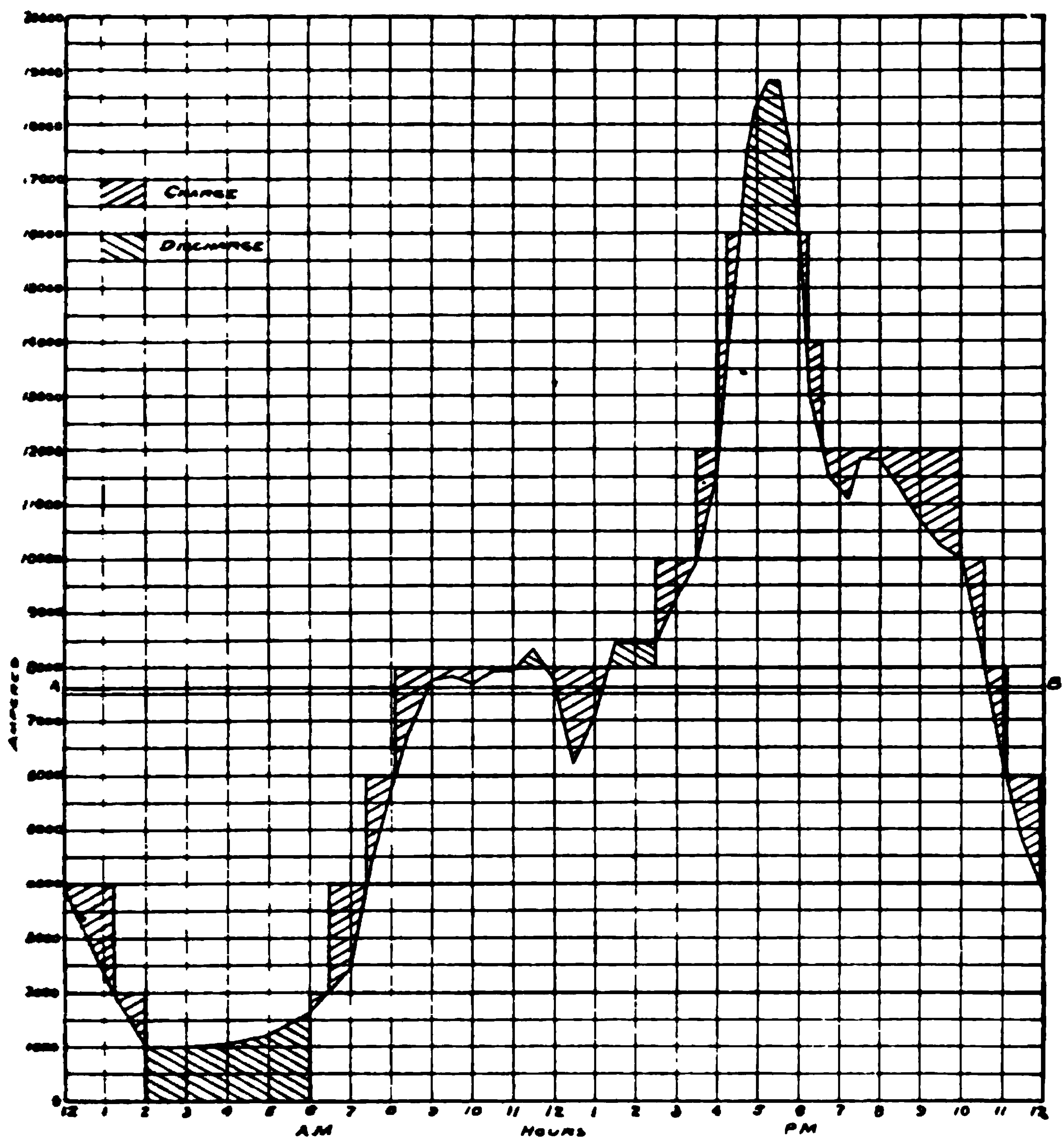


FIG. 2.—LOAD LINE OF A CENTRAL STATION.

amperes, while the average load is only 7,105 amperes, or about 37½ per cent. of this maximum. This is for our present case the load factor, and means that could we by some means provide an adequate method of storing our power, we could get along with

about three eighths of our present investment in generating machinery, and still have sufficient capacity to meet the demand. Under these conditions the load line of the generators would be represented by the horizontal line *A B* drawn at the height of the average current, that is, at 7,105 amperes. This assumes 100 per cent. efficiency of our storage battery apparatus, and is not strictly speaking correct, but will answer for illustration. This storage apparatus would be receiving energy during all the time that the station output was below this average line, and would give it out whenever the output exceeded the capacity of the generators.

It is needless to say that no attempt is ever made to realize this ideally perfect state of things in practice, and the most ardent advocate of the use of accumulators would hardly venture to assert the practicability of attacking the problem in this way. The cost of any system of storage, of sufficient magnitude for the purpose, would cost many times the saving in apparatus dispensed with. As a matter of fact, while present station practice without accumulators can do nothing to lessen the investment below what is necessary for the maximum demand, the actual running expenses are caused to vary approximately with the demand, by a system of properly proportioned units, and the application of storage batteries is limited to the functions mentioned in our previously given classification.

In the accompanying curve these separate functions can be clearly seen. The fourth, referring only to annex stations, is, of course, not applicable here. The areas representing the charge and discharge of the battery are shaded differently. We find that from 2 A.M. till 6 A.M. the entire load is carried by the battery. By properly dividing the men into watches, this would result in a proportionate saving of labor. At 6 A.M. the load has begun to increase rapidly, and the first unit is started up, to be followed in rapid succession by the second, third and fourth. The generator capacity then reached we see is sufficient for our average load, and is actually in service the greater part of the day, or from 8 A.M. till after 11 P.M. As each generator is thrown into service we see that it immediately begins to run at its maximum output, charging the battery until the circuit demand equals its capacity.

This exemplifies the third function of the battery mentioned in our classification, that of an equalizer or reservoir. The energy thus obtained and stored for future use would be largely wasted, did we not have storage facilities for holding it in reserve until needed.

After 9 A.M. we see that the load continues approximately constant till the daily drop at the noon hour. The load has evidently thus far been an industrial one (no doubt largely motors) and has followed the hours of labor. It is noticeable that the slight rises in the load immediately before and after the noon hour were taken care of by the battery, without the necessity of starting up another unit for a trivial load. Shortly before 3 P.M. we see the evening lighting load beginning to come on. There is now a constant increase in the number of units in service as the peak rises, each worked under a constant maximum load, and consequently at maximum efficiency, till 4.15 P.M., at which time eight units are in service, and the load passes their capacity. From then until 6 P.M. the battery takes the apex of the peak. At this hour the lighting load is undergoing a rapid decrease, owing to the closing of the stores, and two units are quickly dropped. The small depression occurring at the end of the rapid decline at about 7 P.M. represents the lull between the closing of the day industries and the opening of the places of amusement, etc. The latter produce a small secondary peak at about 8 P.M. and the load then slowly declines till 10 P.M., when the rapid fall commences, which results in the battery again taking the whole load at 2 A.M.

It remains to determine the size of the battery required here and the consequent saving in dollars and cents, due to its installation. We find from the sum of the step-like areas on the rising side of the curve, that there will be approximately 5,000 ampere-hours (4,899 at 85 per cent. ampere efficiency) available, to be absorbed by the battery during the part of the day before the peak. We find also that the area of battery discharge for the peak is about 2,750 ampere-hours, and that the maximum rate here is 2,800 amperes. We see from our table of percentages that if the whole capacity of the battery is discharged in 1½ hours we may expect to receive at least 60 per cent. of its capacity. There-

fore, to discharge 2,750 ampere-hours in 1½ hours would require a battery capacity of 4,583 ampere-hours; this, however, is based on a constant rate for 1½ hours discharge, which would be 1,833 amperes; as our rate is 2,800 amperes for a maximum, we will need a greater capacity than this. We find that if the maximum rate were continued for the entire 1½ hours that 4,200 ampere-hours would be discharged, while the actual discharge is only 2,750. The average of this is 3,475, and taking this as a basis we find that a battery, to furnish this current in 1½ hours, should have about 6,000 ampere-hour capacity.

In like manner we find that the area of the night discharge is about 4,500 ampere-hours to be available in four hours. Again, consulting our percentage curve we see that we can here count on 80 per cent. of our capacity at the normal rate. This would indicate a capacity of 5,625 ampere-hours, and as there is no excessive discharge likely to occur at this time we will decide on the capacity determined by the requirements of the peak, that is, 6,000 ampere-hours. As to the arrangement of the battery, 150 cells will probably be installed, 75 on each side of the three wire system, and of course the capacity of each cell would be one-half of 6,000, or 3,000 ampere-hours.

This battery, at the rates now available, would cost approximately $35.00 per K. W. H., or a total of about $30,000, and would be maintained by the company installing them, if desired, at say 7 per cent. per annum, thus making

Maintenance	$2,100 00
Interest would add perhaps 6 per cent. to this, or	1,800 00
Attendance would cost, say $60 per month, or	720 00
Making a total per year of	$4,620 00

This is the outlay; on the other hand we have for the gain by installing the battery: *First*, the machinery saved; this in the present case consists of one standard unit and a half unit, which would take the minimum load for a short time and top off the peak; this saving would be at least 375 K. W., and at $100.00 per K. W. would represent a saving of $37,500. We thus see that for a given capital outlay, more capacity can be bought by a judicious proportioning of it between generating and storage

ation. It is, however, a typical case, and as such forms a basis for a deduction. This is, that a great majority of our direct current central stations are being either blindly or willfully operated without due regard to the greatest obtainable economy.

It now remains to specify and describe a few of the storage battery plants recently installed, or about to be installed, in this country. An interesting example of a private isolated lighting plant operated with a storage battery adjunct is that in the residence of Charles T. Yerkes, Esq., in New York City. The plant has as a source of power a 35 to 40 H. P. Otto gas engine; to it are belted a 24 K. W. dynamo and an 8 K. W. booster dynamo. As a precaution against the transmission of vibration to the upper parts of the dwelling, the engine was mounted on a solid concrete block foundation, having a thick packing of cellulose beneath and on all sides of it. This was perfectly successful, and no vibration whatever is perceptible even in the floor and walls of engine room itself. With the switch-board the following operations can be performed: *First*, starting the gas engine, by running the dynamo as a motor from the battery as a source of power. *Second*, feeding house mains from dynamo alone. *Third*, charging battery from dynamo and booster, meanwhile feeding the lighting circuit or not, as desired; the switch-board is quite capable of accomplishing all the changes without any interruption whatever of the house light. *Fourth*, discharging battery in parallel with dynamo into the lighting circuit.

The battery consists of sixty-six cells set up in a single tier, and having a capacity of 400-16 C. P. lamps for ten hours; or if necessary a maximum capacity of 800 lamps for four hours; all the connections between the cells are made by lead burning, there being no bolts or fastenings of any kind used. As the engine and dynamo have a capacity of over 400 lights, we see that there is available for occasions of maximum demand a total capacity of 1,200 lights for four hours, which is about the total number wired in the house. It is believed that this is the largest private domestic installation to be found anywhere at present, and when we consider that the whole plant is running in the basement of a city residence with absolutely no noise or other annoyance to the dwellers therein it becomes additionally interesting. The dimen-

for the active part, and the outside dimensions of the lead-lined wooden tanks in which they are contained, are 33″ x 22″ x 40″ high. The battery is divided into two halves, each operated on a side of the three-wire system, and mounted in two tiers on an iron framework. The battery room occupies the upper floor of the east half of the station, a room 42′ x 22′. The capacity of the battery is 8,000 ampere-hours. Plans are in preparation for a similar battery of 8,000 ampere-hours capacity to be installed in the down-town Bowling Green station of the same company.

Among other stations in which accumulators are about to be installed are the Edison Electric Illuminating Company of Brooklyn, 8,000 ampere-hours, and the Edison Electric Illuminating Company of Boston, 6,000 ampere-hours.

It should be mentioned in this connection that the largest storage battery installation in the world is shortly to be installed by the Electric Storage Battery Company at Hartford, Conn. This will be in connection with the development of water power, and will result in nearly doubling the available power from the fall, besides affording perfect regulation. It will have a capacity of 2,500 K. W. H., and the lead-lined tanks used to contain the plates will measure 21½″ x 55½″ x 41″ high outside; there will be 61 plates in each tank.

An interesting application of accumulators in the direction of power work is now in process of construction for the Manhattan Elevated Railroad of New York City. This in some particulars is quite unique; a third rail will be laid as a means of connection between the power station and the motors, and each motor car will carry a battery of 248 cells of 400 ampere-hours, the weight of which will be about ten tons, which is connected in parallel across the line. The function of the batteries is to prevent great fluctuations in the load due to starting and stopping of trains. The advantages of placing the batteries on the cars rather than in stationary positions along the line are: *First:* that any congestion in traffic results in a corresponding increase in battery capacity at the congested point. Stationary batteries would have to be designed to handle the maximum number of trains possible to each section; this is a large saving in batteries and copper. *Second:* the running of the third rail is much simplified, as it

On the particular day represented by this diagram, the power delivered fluctuated from 63 to 210 H. P., with a mean average of 162 indicated at the engine, or 149 by electrical measurement from the generator. The water rate rose to nearly 29 pounds per indicated H. P., when the engine delivered 50 H. P., but fell to 15 pounds per unit, when 300 H. P. was delivered. Assuming that a storage battery was connected, having sufficient capacity, to equalize within 10 to 20 per cent. of a normal mean, and that the engine was delivering its maximum efficient H. P., the water

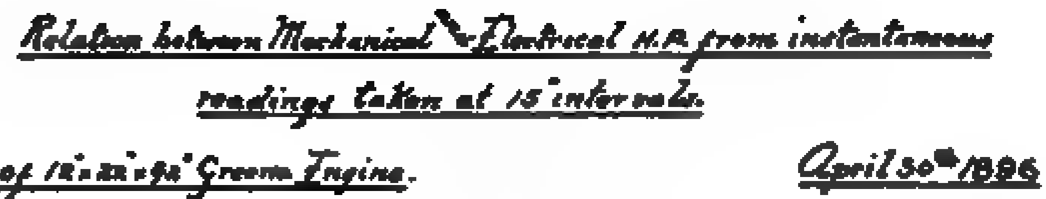


FIG. 3.

rate, or steam passing through the engine, would probably be between 16 and 17 pounds per H. P., whereas under the conditions under which the engine operates, namely a mean delivery of 160 to 180 H. P., the water rate is about 22 per H. P.

MR. KELLER.—Mr. Klauder referred to the small percentage of storage batteries in this country as compared with those in Germany. It is a fact that for many years nearly all of the larger central stations in Germany have been equipped with

capacity that it would have if discharged in 8 hours. The efficiency at different discharge rates does not vary according to that curve.

MR. EGLIN.—In relation to the saving in coal consumption, on account of the uniform running of the engines, on the basis of coal consumption alone, there was a handsome saving by using this battery, but Mr. Klauder has not allowed for a saving in labor. It is evident that this would be large. From midnight to six o'clock in the morning only one man would be necessary in each department. There was a saving of at least $4,000 in labor in one year in the station to which I refer. Mr. Klauder spoke of the central station peak load; there have been various schemes suggested to get rid of the peak load, but this is practically impossible, for the day load will run to six o'clock, and in winter the day and the night loads will meet. We cannot get rid of the peak.

MR. CARL HERING.—I would like to ask whether that curve on the board (Fig. 1) was obtained from one type of cell, or from different types. There is a peculiar inflection point near the right-hand end which seems inconsistent. If that diagram had been continued one space farther to the right, representing zero-hours, the curve should approximately meet the horizontal zero line, as was shown by tests which I made with one of the same company's cells; it therefore seems inconsistent to have a point of inflection where it is shown.

MR. KLAUDER.—The curve is from experiments on one type of battery, and the very fact that the curve took that form, was the reason why the experiment was repeated once or perhaps twice, always, I understand, with the same result. I have had it explained to me in this way, that the amount of active metal brought into play in a discharge is decreased as the rate of discharge increases, and that finally only the active material on the surface is brought into play. If we take plain lead oxidized plates, the active material is entirely on the surface, so that no matter how rapid the rate of discharge may be it will all be available, and we may say that the capacity of such an accumulator will not fail. There is a point in every accumulator when we reach that condition, that is, the state of things in which only

the surface is available; there is no time to go below the surface. At that point the curve takes the upward curvature.

MR. LANDIS.—Mr. Klauder said he could get twice as much illumination out of the same amount of gas by burning it in an engine and dynamo than by burning the gas directly. Would he use a fish-tail or a Welsbach burner? I also understand that the energy stored diminishes when the battery is not in use for some time. How rapid is this loss?

MR. KLAUDER.—The tests for determining the first question were made with an ordinary burner. In regard to the other question, I believe that a battery could stand idle all summer without losing any appreciable amount of its power.

MR. APPLETON.—Questions have been asked about the efficiency for different rates of discharge. When the rate of discharge is increased the efficiency does not fall a corresponding amount. About the only loss is from the C^2R effect due to the internal resistance of the battery. When you are discharging at a high rate this loss is more, and that is the only reason for the reduction of efficiency for a high rate of discharge. For instance, if you take the efficiency of a battery at the eight hour rate as about 80 per cent., you would probably get about 75 per cent. at a one hour rate. I would like to make one or two remarks in regard to Mr. Keller's statement that if the price cannot be reduced there will not be many batteries sold. If what he said is correct, batteries would still be sold, as the price is not excessive when compared with other pieces of electrical machinery. Batteries compare favorably with the cost per kilowatt of the dynamo. There are conditions where the storage battery is invaluable. The question of electric elevators is coming to the front. A large building in New York had 6 high-speed electric elevators, and the fluctuations at 220 volts varied in a half minute from 10 amperes to 600. A battery here would soon pay for itself. One other point is, the future of the storage battery. All central station men are trying to overcome the peak, and in this connection I would like to mention something which is being tried by one of the largest direct current stations in this country. They will supply customers with current at greatly reduced rates during eighteen hours out of the twenty-four. Their customers will install batteries

and charge them during this time. This will enable them to fill up the dip in the load line, and in large cities this will greatly assist in leveling the load line. There is a building in New York which has been remodeled, and in a few weeks will be one of the finest in the city. The engineer very carefully considered what sort of a plant he should put in, and he has adopted the plan of putting in one engine and dynamo and two storage batteries, all of equal capacity. He is running lights and elevators; he will run the engine and dynamo at full load during all the time that they are running, charging up each battery alternately; the other battery will be used for supplying the lights; the elevator load will be carried by the battery which is being charged; the lighting load will be steady. With regard to cost he finds that the difference of the two systems shows a saving in favor of his own system of about $200 in the first cost of the plant.

Mr. Hering.—What was the total cost of the plant, of which this $200 represents the saving?

Mr. Appleton.—About $40,000. I mention it to show that the cost of a plant of this kind is not greater than that of other plants. I did not say that the use of a battery would reduce the cost of a plant, but that it would not make it excessive.

Mr. Keller.—I would like to say to Mr. Appleton, who took exception to my remarks, that it was not my intention to say that the storage battery is an excessively expensive piece of machinery. I merely compared it with that of the batteries in Germany. I think the batteries should be cheaper here.

VIII.

THE WATER SUPPLY OF PHILADELPHIA: CONSIDERED WITH REFERENCE TO THE MINIMUM FLOW OF THE SCHUYLKILL RIVER.

By Edwin F. Smith, Active Member of the Club.

Read, September 19, 1896.

The city of Philadelphia obtains its supply of water for domestic and manufacturing purposes from the Schuylkill and Delaware rivers, pumping approximately 94 per cent. of its supply from the Schuylkill, and 6 per cent. from the Delaware. There are no impounding reservoirs under the control of the city upon either of these streams. The city is therefore entirely dependent upon their natural flow.

The area of the watershed of the Schuylkill above Fairmount dam is 1,900 square miles. The area of the watershed of the Delaware above the Frankford pumping station is 8,100 square miles.

The location of the principal pumping stations and the most costly machinery, with the distributing reservoirs connected therewith, on the Schuylkill side of the dividing ridge between the two rivers, demonstrate the almost entire dependence of the city on the Schuylkill river. This condition might seem like a reversal of the proper order of things, to the mind of an engineer unacquainted with the history of the works, and unaware of the local prejudice which has for years existed against the use of Delaware river water for domestic purposes. The first city water works were located upon the Schuylkill, and work upon them commenced as early as March, 1799. From that date until the present time, the works have been added to and the system extended, as the needs of the city required.

At the present time there is probably no larger nor more costly installation of water works pumping machinery in the world. It comprises, including two under construction at Queen Lane Station, thirty-two pumps driven by steam, and seven by water power, of an aggregated designed capacity of 412,290,000 gallons per day, divided between six main and four auxiliary stations.

Included in this array of costly machinery, there are eight high duty pumps of a capacity of 20,000,000 gallons each, and two of 30,000,000 gallons. Surely Philadelphia has reason to be proud of her pumping stations.

Whether owing to the abnormal increase in the consumption of water by the inhabitants, or to the more frequent recurrence of droughts, and the consequent diminished flow of the river, the city is now pumping and consuming from the Schuylkill, during periods of drought, a quantity of water greater than the available flow of the stream. A knowledge of this fact has led me to tabulate some statistics bearing upon the relations existing between the maximum consumption of water by the city, and the minimum flow of the river, which may be interesting and of sufficient value to be preserved for future use. In presenting these figures, I desire to give credit to the Water Department of the City for those referring to pumpage and the consumption of water, as well as for other data connected with the operation of the works, all of which is admirably tabulated in the yearly reports.

Philadelphia covers an area of 129 square miles, and contains a population of about 1,300,000. When 94 per cent. of the pumpage of the water supply of so large a city is from the natural flow of a comparatively small stream, a large storage capacity in distributing reservoirs is required. In other words, what is lacking in impounding capacity within the drainage area of the stream pumped from, must be made up in reservoirs on the distribution side of the system, unless the natural flow is large enough at all times to supply the pumps.

The practice of the Bureau of Water for years past has been to base its estimates of the capacity of the Schuylkill, as a source of supply, upon the *average daily flow.*

Referring to the report of the department for the year 1895 (p. 406), the rainfall and stream flow is stated as follows:

Year.	Rainfall.	Total Annual Stream Flow in Gallons.
1894	51.76	638,858,680,237
1895	35.78	368,306,402,874
Decrease		270,552,277,363

and the annual pumpage from the Schuylkill:

1894	67,158,206,339	pumpage gallons
1895	73,106,159,093	"
Increase	5,947,952,754	"

The same report states further that "reliable statistics of the flow of the Schuylkill during past years are not at command," and "From such data as we have, Mr. Codman roughly estimates the *average daily flow* of the Schuylkill at Fairmount for the entire year, at about one billion gallons." The general reader would infer from such statements that the average daily flow, in 1895, of 1,000,000,000 gallons could be so conserved and regulated as to furnish an average daily pumpage approximating 200,000,000 gallons.

However misleading, in the absence of other data, these statements may seem, indicating as they do, that the source of supply is greatly in excess of the demand, the situation is not misunderstood by the Water Bureau, as the following quotation from the report for 1895, shows:

"The average daily flow of the Schuylkill, *throughout the year*, may, as already remarked, be taken as about one billion gallons.

"This, *if it could all be rendered available*, would suffice for the entire needs of the city until 1950, supposing the consumption to continue at its present rate.

"Much could be done in this direction by the construction of impounding dams, in which to store for use in the dry season some of the water which now goes to waste in floods. Such a plan, it will be remembered, was under consideration by the Commission of Experts, appointed in 1875; but the Commission held that it *would be much more expensive than raising the additional water by steam at Fairmount*, and did not therefore recommend it."

And again, in commenting on the proposed storage reservoirs in the Perkiomen Valley, Mr. Trautwine says:

"If storage reservoirs could be made of such capacity that all of the water of the streams could be impounded, *the average rate might be used*, and the shortage occurring during the periods (of drought) referred to, would be compensated by the excess stored during the others."

It would be safer, therefore, to eliminate all references to the *average flow* of a stream upon which the city has *no impounding reservoirs*, and to deal only with its *absolute minimum flow* in years of extreme drought and with its *low season flow* in ordinary years.

The minimum flow of various streams east of the Allegheny Mountains has been ascertained by measurement to be about 0.15 cubic feet per second per square mile of drainage area, and it falls below that figure only at long intervals. The ordinary low season flow of the same stream may safely be taken as 0.24 cubic feet per second per square mile. The former figure applied to the watershed of the Schuylkill River above Fairmount dam gives a minimum flow of 185,000,000 gallons per day in periods of extreme drought, and the latter figure gives an ordinary low season flow of nearly 300,000,000 gallons per day.

Illustrating this branch of the subject, I have prepared the accompanying Table I, showing the minimum flow of the Schuylkill River at Fairmount dam, compared with the average daily pumpage during the months of maximum consumption, from 1869 to 1895, inclusive.

An inspection of the figures shows that two protracted and extreme droughts have occurred in the Schuylkill valley in twenty-seven years, the first from 1887 to 1881, inclusive, and the second from 1892 to 1896, inclusive. During both these periods the average rainfall fell below the average for the twenty-seven years, 43.12 inches; in the first period 6.15 inches below, and in the second 1.47 inches below. But with respect to the second period of drought it must be taken into account that the rainfall of the month of May, 1894, was abnormal, being 11.92 inches, or nearly 28 per cent. of the annual.

The absolute minimum flow of the river, 167,000,000 gallons per twenty-four hours, occurred in 1881 with an annual rainfall of 37.94 inches in that year, 35.61 in 1880, and 35.94 in 1879. These are unusual conditions and very rarely prevail.

The minimum flow of 1895, which was 185,000,000 gallons, with 34.70 inches rainfall in that year, exceeded the flow of 1881, 167,000,000 gallons, only 10.8 per cent.

The drought of 1892–95 was broken by the evenly distributed

rainfall of the year 1893, and the abnormal rainfall of the month of May, 1894. The condition of drought still prevails during the present year, the flow of the river having fallen to 194,000,000 per

TABLE I.

Schuylkill Navigation, the quantity let down in [illegible] being [illegible] gallons.

day in September, 1896, equal to 0.158 cubic feet per second per square mile, following the least monthly rainfall of any month of August, of which we have a record, in the valley of the Schuylkill.

Compared with the Schuylkill, the minimum flow of some American streams, which have been accurately gauged, is as follows:

From 10th Census of the United States, Vol. 16, "Water Power":

			Drainage Area in Square Miles.	Minimum Cu. Ft. per Sec. per Sq. Mile.	Observer.
Concord	River, Lowell, Mass....		361	0.17	C. Herschel.
Housatonic	"		790	0.165	H. Loomis.
Croton	"		338	0.15	J. J. R. Croes.
Passaic	"	Paterson, N. J...	813	0.22	"
Hudson	"	Palmer's Falls..	2,650	0.147	Mr. Curtis.
Ohio	"	Pittsburgh........	19,900	0.114	J. H. Harlow.
Kanawha	"	Charleston	8,900	0.123	Gill, Scott & Hutton.
Shenandoah	"	Port Republic...	770	0.167	James Herron.
James	"	Richmond........	6,800	0.191	Whitcomb&Cutshaw.

The above figures are sufficiently accurate to form a basis for calculating, approximately, the minimum flow of streams in the localities named; but in some cases, for want of long-continued observations, the gauging may not have occurred in the driest year. The best results correspond with my own observations on the Schuylkill; and I therefore repeat that if the figure 0.15 cubic feet per second per square mile be applied to the 1900 square miles of watershed of the Schuylkill above Philadelphia, and proper allowance be made for the water diverted from the stream for the supply of towns and manufacturing establishments, and for lockage and leakage at Fairmount, the result will be as nearly as possible the available supply, during low water seasons, which can be depended on for the pumping stations of the city of Philadelphia.

In 1895 the quantity of water taken from the river above Philadelphia for domestic and manufacturing purposes, and not returned to it, was estimated from pumpage and other data to be 13,500,000 gallons per twenty-four hours. In the same year the

838,000,000 gallons from the up-river dams of the Schuylkill Navigation, in the effort to pass the boats navigating the river.

The existing conditions may be more readily understood, by an inspection of the diagram, Fig. 1, showing for each year from 1869 to 1895, inclusive, the minimum flow of the river, available for city supply, the steam and water power pumping capacity of the water works located on the Schuylkill, and the average daily pumpage, during the month of maximum consumption.

The diagram shows that the city *exceeded in its pumpage the available minimum flow of the river* in 1895, and again for a short time, early in September, 1896.

On the former occasion, but for the timely aid given by feeding from the upper pools of the navigation, the result would have been a restriction in the use of water, both for domestic and manufacturing purposes.

These conditions were made more alarming by the fact that two of the city reservoirs (Queen Lane and Roxborough) were out of service, reducing the total storage capacity, with full basins, to 800,000,000 gallons, or only 3½ day's supply, at the then rate of consumption, and by the fact that the reservoirs in actual use were drawn down below a safe working limit, emphasizing the fact, already referred to, that a large city, having vast interests at stake, must have an abundance of water stored for such emergencies, either in impounding dams on the stream or its branches, forming the source of supply, or in distributing reservoirs in or near the city. Philadelphia, though the third city in size in the United States, has fallen from the front rank it held early in the century, to a very low place in the list of cities, in the matter of a safe and abundant water supply.

I have been so impressed with this fact that I have prepared the accompanying Table II, comparing the reservoir capacity and other features of the water supply of ten cities east of the Allegheny Mountains, dependent upon pumping from streams, and upon gravity supplies. The most noticeable feature is the very large storage of such cities as New York, Boston and Newark, N. J., all of which are dependent upon streams upon which it has been necessary to create storage. The table speaks for itself, and any further reference to it is unnecessary.

Fig. 1.—Minimum Flow of the Schuylkill River.

Table II.

Population (1890) Reservoir Capacity (1895) Consumption per Capita of Cities Named.

Cities.	Population — Census of 1890.	Source of Supply	Area of Water Shed — Square Miles	Consumption per Capita, 1890. Gallons	Consumption per Capita 1895 Gallons	Reservoir Capacity Impounding & Distributing. 1895, Gallons	Additional Reservoirs under Construction 1896. Gallons.	Number of Days storage [C] Provided for Estimated on basis of Reservoirs in use and under construction at 1895 rate of consumption per Capita.
New York	1 515 301	Croton River / Bronx "	352	79	105	40 043.000.000	40 900.000.000	428
Philadelphia.	1 046.964	Schuylkill River & / Delaware " "	1900 / 8100	132	160	1 333 000.000 [A]	none	6.4
Brooklyn	806 343	Ponds & Driven Wells	154	67	79	1.721 700.000	none	21.5
Boston	448.477	Cochituate River / Sudbury "	121	80	100	9.306.000.000	7 400.000.000 [B]	350
Baltimore	434.439	Jones Falls / Gunpowder River	334	94	100	2 400 000.000	none	52
Washington	230 392	Potomac River	11476	158	170	331 080.000	300 000.000	15
Newark, N.J	181 830	Pequannock River	64	76	110	6.600.000.000	2.500 000.000	413
Providence, R.I	132.146	Pawtuxet River	192	48	57	152.000.000	none	18
Troy, N.Y	60.956	Piscawen Creek and Hudson River	4500	125	132	280.000.000	none	28
Reading, Pa.	58.661	Branches of Schuylkill River	332	75	95	180.000.000	1 019 000	25

Note. A. Of the 1,333,000,000 gallons reservoir capacity of the City of Philadelphia, only 800,000,000 gallons (approximately) in service ... Queen Lane basins.

B. The Metropolitan Water ... under construction, a new storage reservoir, on the Nas...

C. Number of days storage ... in the absence of statistics of available storage.

TABLE III.

TABLE showing the Combined Capacity of the Pumping Stations supplying the City of Philadelphia with water from the Schuylkill, Capacity of Distributing Reservoirs, Maximum pumpage and Total Pumpage per Capita.

1881 —— 1895

Year	Pumpage Capacity of All Schuylkill Works. Gallons per 24 hrs	Reservoir Capacity Supplied from the Schuylkill River. Gallons.	Maximum Pumpage from the Schuylkill. Daily Average Gallons.	Total of all the Works. Delaware & Schuylkill. Average daily pumpage for the Year. Gallons.	Population.	Total Pumpage. Gallons Per Capita.
1881	not given	129,716,840	61,399,245 August	62,249,355	869,000	71
1882	" "	129,716,840	69,567,708 July	67,647,782	890,000	76
1883	109,250,000	129,716,840	73,003,154 "	69,273,856	911,000	76
1884	136,750,000	129,716,840	67,311,474 August	69,658,969	932,000	76
1885	133,900,000	129,716,840	70,919,117 July	68,945,260	953,000	72
1886	133,900,000	129,716,840	80,774,181 "	78,433,289	975,000	80
1887	153,900,000	189,716,840	96,004,901 "	88,840,492	995,000	89
1888	156,040,000	495,716,840	103,434,548 August	101,280,774	1,020,083	99
1889	156,040,000	802,162,814	119,166,413 September	116,490,191	1,050,000	111
1890	162,040,000	802,162,814	150,176,770 "	141,639,749	1,046,000	135
1891	162,040,000	802,162,814	159,012,432 "	152,508,624	1,071,672	142
1892	179,790,000	802,162,814	167,283,589 June	163,801,600	1,142,650	143
1893	205,790,000	950,162,814*	186,210,903 "	179,048,594	1,190,493	150
1894	235,790,000	950,162,814*	202,886,263 October	197,344,806	1,238,112	159
1895	305,790,000	1,333,270,854*	215,501,882 September	215,824,244	1,329,957	162

*NOTE Queen Lane and Roxborough Reservois not in full use, actual Reservoir Capacity in 1893 - 4 and 5 about 800,000,000. gallons

In conclusion, the great need of Philadelphia, if it retains the Schuylkill as the source of supply, is *enlarged storage capacity.* Whether this should be obtained by means of impounding dams within the drainage area of the stream, or by additional distributing reservoirs to be filled by pumping when the river is at its normal stage, it is not within the scope of this paper to discuss. It is sufficient to say that if enlarged storage capacity is to be obtained by means of impounding dams, within the drainage area of the stream, there are opportunities within easy reach, such as few cities possess.

Within the drainage area of the Perkiomen, the principal tributary of the Schuylkill, there may be created, at a cost scarcely exceeding that of the Queen Lane and Roxborough basins, three impounding reservoirs of a combined capacity of nearly 20,000,000,000 gallons, and at an elevation sufficiently high to feed through an aqueduct, by gravity, into the Queen Lane reservoir.

Such an extension would add a feature of permanence which the present water works system of the City of Philadelphia does not possess.

DISCUSSION.

MR. JANVIER.—Have you any data in regard to large western cities?

MR. SMITH.—I have not included any western cities. I thought it best to confine myself to eastern cities. Chicago has an installation of pumping machinery that would perhaps rank second in size in the United States, being exceeded only by that of Philadelphia. The supply of Chicago is by direct pumpage from Lake Michigan. Detroit is supplied by direct pumpage from the Detroit River. St. Louis is situated in a flat country, and there is therefore no opportunity for impounding reservoirs. The city is supplied from the Mississippi River, pumping to settling basins, and thence repumping through standpipes and distribution system to reservoirs. There are some large installations of both pumping machinery and reservoirs in the West. In the matter of impounding dams, they are, I think, ahead of us in the East. In California and Colorado some very large

dams have been built within the last fifteen years both for water supply and irrigation.

MR. TRAUTWINE.—I think Mr. Janvier's point well taken. To render complete the table comparing the reservoir capacity of Philadelphia with that of other cities, it should have shown the conditions existing in cities like St. Louis and Chicago, which have practically inexhaustible supplies of fresh water at their doors, with few or no suitable locations for the construction of storage reservoirs. Towns so situated necessarily depend upon pumpage capacity rather than upon reservoir capacity. The great river or lake close at hand is their reservoir, and the pumps provide the necessary elevation, whereas, in cities like New York, with no fresh water close at hand, and with excellent reservoir sites in the near neighborhood, great storage reservoirs are built to compensate for the lack of ample natural fresh-water storage close at hand.

Philadelphia occupies, in this respect, a position midway between these two extremes. Remote from any plentiful supply of unexceptionable water, but with exhaustless volumes of fresh (though not pure) water flowing past her doors, and with high ground near at hand and within her own borders for the construction of artificial reservoirs of moderate size, she combines to some extent the two systems, using her pumps for the elevation of the water, and depending upon her reservoirs for some measure of elevated storage and of subsidence.

MR. SMITH.—I should like to emphasize one point, and that is, that the western cities mentioned are pumping from the great lakes and from large rivers. I have endeavored to show the fallacy of pumping from any small stream, the natural flow of which is less than the needs of the city, without providing ample impounding reservoirs. The Delaware is at our doors, but the pumping stations are not on it; they are on the Schuylkill. I have endeavored to show the existing conditions. Detroit has a connecting link in the chain of great lakes to pump from. Chicago pumps from Lake Michigan; St. Louis pumps from the Mississippi River. The supply of water in these sources is very far in excess of any requirement of those cities for years to come. I have no doubt that if Chicago had been situated

upon an inland salt sea, she would have gone to the lakes of Wisconsin long ago. She would not have sat with hands tied facing a possible calamity through the loss of her water supply, nor would she have postponed the work very long. No matter what may be said of corruption in city government, it is not apparent in the public works of either Chicago or New York. Chicago has grown because she is enterprising. Her new drainage canal, now building, is a splendid example of municipal enterprise, and the same may be said of the waterworks systems of New York and Boston.

MR. TRAUTWINE.—Chicago, having the lake at hand, has not had recourse to a distant source of supply. Philadelphia, having reached the limit of supply of the Schuylkill, would, if it were not for the Delaware, be compelled to seek a more distant source. But, having the Delaware, is it not the part of wisdom to make our further developments in that direction?

It is true that the Delaware is subject to pollution from the city's own sewers, but as yet to no very great extent, and its volume is so large and the pollution from up-stream relatively so small that its waters compare not unfavorably with those of the Schuylkill. Besides, there is reason to believe that a system of filtration, properly designed, will render the waters of both rivers perfectly satisfactory for domestic and other uses.

MR. EDWARD K. LANDIS.—I would like to call attention to the difference between the Croton and the Schuylkill watersheds. The former has less timber on it, and less soil, with more rock, and the flow-off comes nearer the total rainfall than in any other watershed that I know off. The Schuylkill watershed is exactly the reverse. Another feature is the difference in the topography of the two regions. In New York there are quite a number of valleys with narrow, contracted necks, where a small dam will hold an immense quantity of water. The watershed of the Schuylkill does not lend itself readily to impounding reservoirs, which could only be built at considerable expense. I would like to ask, in view of the use of Delaware water, how the watersheds of our two rivers compare in the matter of population per square mile?

MR. SMITH.—I think the average population per square mile

is greater in the Schuylkill watershed. The upper Delaware is sparsely settled, whilst in the mountain region of the Schuylkill area there are several large towns on the borders of the anthracite coal region. In considering water supply, a distinction should be made between the population living in towns and cities *on the banks of a stream*, and that which is scattered over a wide expanse of country, far from the main stream or its tributaries. The population in towns and cities on the Schuylkill river, and its tributaries above Philadelphia, does not exceed 150,000, and is not as high as 400,000, as has been reported. Of this, 75,000 are in the city of Reading, which has in operation an efficient sewage disposal plant.

Mr. Landis.—How does that compare with the Delaware?

Mr. Smith.—I could not say in exact figures. I can only say, in the absence of statistics, that the average population of the 1800 square miles of watershed of the Schuylkill, above Philadelphia, is greater than for the 8,000 square miles of the Delaware. Nevertheless, the average per square mile in the Delaware district is large. Trenton, Easton, Bethlehem, Allentown and Mauch Chunk are all sewered, and the discharge is directly into the rivers.

Mr. Landis.—Do you think it is 2 to 1?

Mr. Smith.—I think not.

Mr. Furber.—In reply to the question of Mr. Landis as to the relative population in the two watersheds, Mr. Allen Hazen's report to the Woman's Health Association, published in the Philadelphia *Record* of this morning (September 19th), gives the urban population of the Schuylkill watershed as 63 per square mile, and of the Delaware watershed as 23 per square mile.

Mr. Lockwood.—As a stranger here, I would like to ask a few questions. I was Chairman of the Philadelphia Board of Trade. I would like to ask what the impounding capacity of the Schuylkill supplies are?

Mr. Smith.—I could not give those figures. I only know that the available impounding capacity of the navigation dams on the river is about 4,500 million gallons. There are no dams above the Blue Mountains.

Mr. Lockwood.—This capacity might be increased. A Swiss

engineer, who is with us, and another gentleman here, were surprised to see that there was such a large waste of water. Engineers who were visiting this country were surprised to see how little power was used on the Schuylkill. They said there was enough power there to light the city by electricity. How far does the flood tide carry the sewage of the city up-stream?

MR. TRAUTWINE.—Strictly speaking, probably as far as the flood tide runs. As a matter of fact, however, bacteriological examinations made in 1895 by Dr. Bolton, Bacteriologist of the Board of Health, showed that the Delaware water, taken from Wentz Farm reservoir, compared fairly well with that taken from the Schuylkill reservoirs, being much better than some, and if I remember rightly, not much worse than the average. The flood tide carries up not only the outflow of the city sewers, but also that of Frankford Creek, the mouth of which is about a mile below the pumping station, while from above we receive the discharge of Pennypack Creek (two miles above) and two small city sewers emptying between the pumping station and the Pennypack. The Pennypack brings the sewage of the House of Correction, but, after examining the outlet, I believe this to be but a drop in the bucket compared with the other sewage emptying into the Pennypack further up. The intake at Frankford extends pretty well out into the stream and is placed at a low elevation. Altogether, the situation is incomparably better than that which existed at the old Kensington station, which took its water, almost literally, from the mouth of a sewer, and the abandonment of which, a few years ago, was marked by a notable improvement in the health of the district supplied by it. Still, the neighborhood of the present Frankford pumping station has been built up enormously within recent years, and it is doubtful whether, even with the possibilities of filtration in view, our pumpage at that station should be greatly extended.

I beg to suggest one correction in Mr. Smith's table of reservoir capacities. We are now carrying, habitually, from 900 to 1,000 million gallons, although Queen Lane and Roxborough reservoirs are still under repair.

THE PRESIDENT.—I would like to ask whether impounding the waters of the Perkiomen would furnish a sufficient supply for the city.

Mr. Smith.—I have hoped that I would not be asked any questions on that point. If it were left to me to decide, my judgment would be that it would be better not to pump direct from the Schuylkill; it would be preferable to impound the water of its tributaries and bring it to the city by aqueduct. The larger part of the supply should come from the Delaware river. The Schuylkill river is the natural drain of a populous valley, and if we continue pumping directly from it, filtration will certainly have to be resorted to. The evil effects of the pollution of water can be very much modified by sand filtration, but that is an expensive mechanical method of overcoming the trouble. It would materially better the situation to go to a pure source of supply.

Dr. Henry Leffmann.—Any system of water supply, which involves the use of surface water gathered from a district liable to become populated, or to undergo industrial development, must provide for efficient storage and filtration. The trend of modern scientific inquiry in this field is decidedly toward the view that surface water is liable to contamination in so many ways, and has, in its natural condition, such limited opportunities for purification, that it never can be safe for use directly.

Apart from any danger of such pollution, which is difficult to prevent, it is interesting to note that recent researches have shown that malarial fevers are conveyed by water, and that the common mosquito is the intermediate host for the germs of these fevers. The mosquito usually seeks water and dies in it. Its body being decomposed, the germs are distributed through the water. Even if the mosquito dies before reaching water, the malarial germs may go into a resting condition, and remain capable of development for a long period; and the dust of the roads and fields, blown into the water, will convey disease.

It seems that, as far as regards Philadelphia, the most satisfactory method would be to efficiently filter the large supply of water which we have in the Delaware river within the city limits. Such a system would give to the city a supply of water, clear, pure and abundant.

IX.

THE CEMENT LABORATORY OF THE CITY OF PHILADELPHIA, ITS EQUIPMENT AND METHODS.

By Richard L. Humphrey, Active Member of the Club.

Read October 3, 1896.

Introduction.—The Testing Laboratory (Department of Public Works, Bureau of Surveys), consisting of the Cement, Physical and Chemical Laboratories, occupies Rooms 56, 58 and 60 in the southwestern portion of the Public Buildings. In the first mentioned of these laboratories is inspected and tested practically all the cement used in municipal work.

While the inspection and testing of cements was inaugurated in the Bureau of Surveys in the early part of 1890, it was not until the fall of 1892 that a laboratory was permanently established. Since that time it has been in constant service, each year multiplying the amount of work to be done, by the increasing demands made upon it by the various city bureaus. The scope of its work has at the same time been gradually broadening—this development necessitating increased facilities. Although seriously hampered by insufficient force, the amount of work accomplished has been very great.

During the last four years there have been collected over 2,000 samples of 66 different brands of cement, both natural and Portland; the testing of these has involved the moulding of over 30,000 briquettes, of which over 25,000 have been broken. With the constantly increasing skill and experience, a system has been gradually evolved, until to-day it is well established and in successful operation.

It will be the endeavor of this paper to explain in detail the apparatus employed and the system under which all cement used in city work is inspected and tested.

A set of specifications (whose requirements are fixed in a manner to be described further on), adopted as the city standard, form the basis for the acceptance or rejection of a shipment of cement.

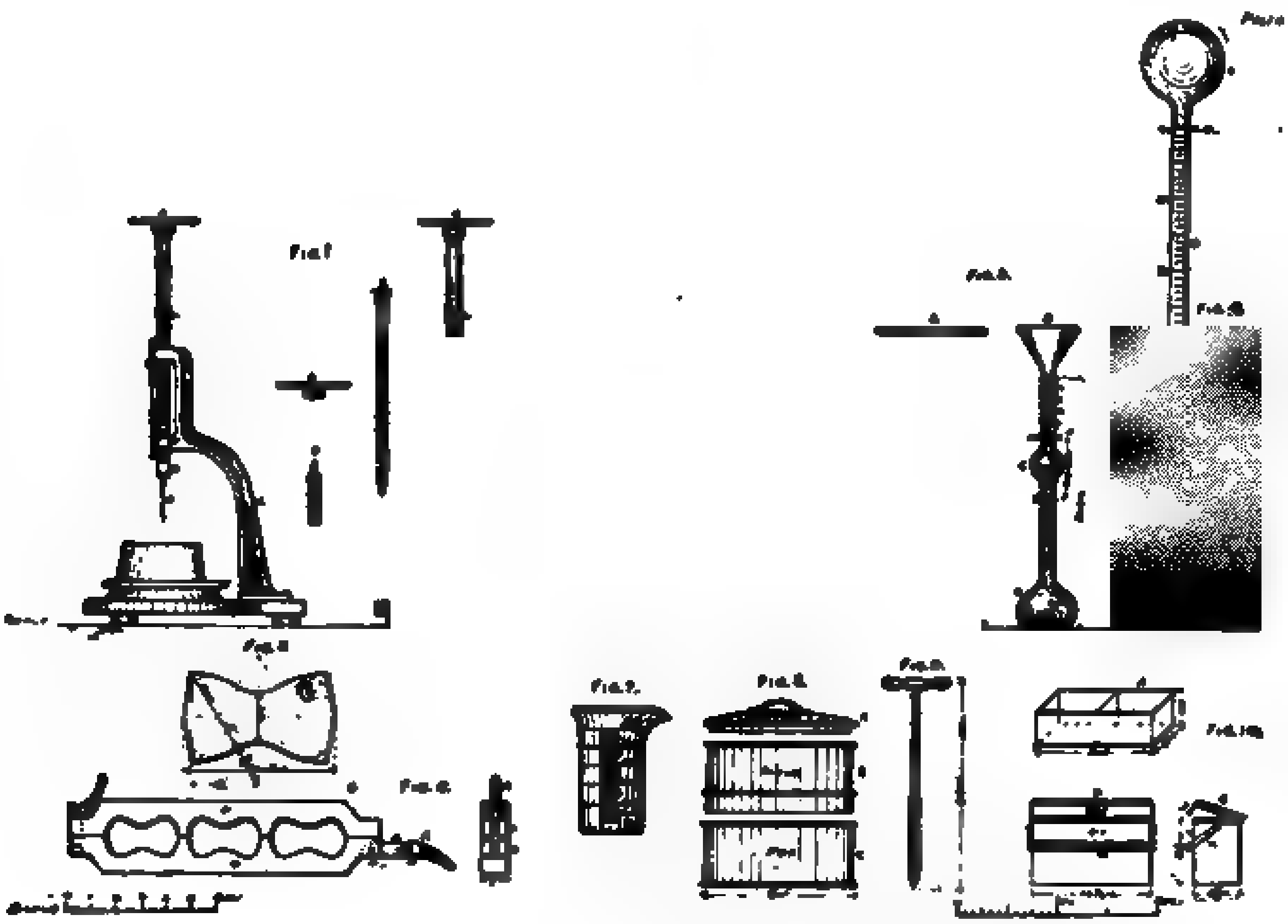
Immersion Tanks. Mixing Table. Moist Closet. "Hot Water" Apparatus.

Fig. 11.—View of the Cement Laboratory.

Any brand of cement is permitted to be used which meets these requirements.

COLLECTION.—The tests are made from samples taken from actual shipments on the work, and not from samples furnished indiscriminately.

Notification of Shipments.—Each inspector is supplied with printed postal cards, which he fills out and mails immediately to the Inspector of Cements, upon the receipt of each shipment of cement on his work. This card states the brand and the number of bags or



FIGS. 1 TO 10.—DETAIL APPARATUS USED IN MAKING CEMENT TESTS.

barrels in the shipment, together with the time and place of delivery, and the purpose for which it is to be used. The shipment is inspected and a sample is taken, sufficient for the required tests.

Sampling.—This sample is obtained by taking a small quantity from one barrel in every five or ten, depending on the size of the shipment, the cement being taken from the heart of the barrel in order to secure a fair sample of its fineness and quality. In large shipments (500 barrels and upwards) a small hole is bored

near the middle of the barrel, through which the sample is drawn by means of a sampling auger, Fig. 9. The notification card is placed on this sample.

Collection Cans.—The sample is brought to the laboratory in special collection cans. There are two types of these cans, one holding two, and the other four samples. The latter type is shown in Fig. 10. They are made of japanned tin and are in two parts; the can proper, *K*, holding two samples, and the upper tray, *A*, holding the remaining samples, fitting into the can, *K*. Each compartment is 7 inches long, 5 inches wide and 4 inches deep, and holds about seven pounds.

RECORDING.—On reaching the office the notification card is replaced by one bearing the laboratory number by which the sample will be referred to thereafter. The data on the notification card is entered in the Record Book, which eventually contains all the information relative to this sample, a record being kept of the number of the sample, the brand, the date and place of collection, whether the shipment was in bags or barrels, the fineness in per cent., date and hour of moulding the briquettes, time of setting and the temperature of the air, the specific gravity, the results of the hot water tests, and the tensile and compressive strength, both neat and with various proportions of sand for different periods of time.

The plan, Fig. 12, shows the general arrangement of the various laboratories; the positions of the various apparatus (which have been arranged so as to afford the greatest convenience), is shown in detail in the Cement and Chemical Laboratories.

MAKING BRIQUETTES.—For weighing the material to be used for making the tests, the laboratory is provided with a pair of scales sensitive to ½ gramme under a load of 2 kilogrammes in each pan. The mixing and moulding is done on a specially-designed table (Figs. 11, 12 and 14), consisting of two parts, each having a plate glass top, one 24 inches long by 18 inches wide, on which the mixing and moulding is done; and the other, which is 3 inches above the level of the former, is 4 feet long, 2 feet wide, and is used for making the tests for time of setting, and for marking and removing the briquettes from the moulds.

The sample of cement collected as just described, composed of

portions taken from various barrels, is now thoroughly mixed by passing it through what is known in the Laboratory as a No. 20 sieve. A small portion is then weighed out and made into a paste by gradually adding clean water from a graduate (Fig. 7). The quantity of water required to produce a stiff, plastic paste, of about the consistency of moulding clay, is thus obtained.

FIG. 12—GENERAL PLAN OF THE LABORATORIES.

A.A.	Immersion Tanks.	G.	Weighing Table.	N.	Sink.
B.	Moist Closet.	H.H.	Waste Cans.	P.	Reagent Closet.
C.	Shelves.	K.	Apparatus Closet.	Q.	Balance.
D.	"Hot Water" Apparatus.	L.	Hood.	R.	Microscope.
E.	Mixing Table.	O.	Working Table.	S.	Wash Basin.
F.	Testing Machine.	M.	Table for Distillations, etc.		

Neat.—Having determined, by the above test, the proper percentage of water required for the neat tests, 1000 grammes of the sample are weighed out, and placed upon the mixing table; a basin is then formed with this material, into which the proper percentage of clean water is poured, the material is turned into the basin by the aid of a trowel, and the mixing is completed by thoroughly kneading the mass to the proper consistency with the

hands. It is then firmly pressed into the moulds with a trowel and the surface smoothed. The mould is then turned over, and the same operation is repeated. The briquettes are kept in the moulds until they can be removed without injury.

Moulds.—The moulds are of brass, both single, and in gangs of three and and five. The three-gang mould is shown in Fig. 6; it is in two parts, *D—D*, to facilitate the removal of the briquette, the parts being held together by means of a clamp, *A—B*. The gang-moulds are usually used, the briquettes being moulded three or five at a time, according to the rate of setting.

The form is that recommended by the American Society of Civil Engineers, except that the corners have been rounded by curves of ½ inch radius. This form has been found to be more easily moulded, and afterwards more easily adjusted in the testing machine.

The moulds are kept clean, and, before the briquettes are moulded, are wiped with a cloth moistened with machine oil.

With Sand.—In making the sand briquettes, the following method is pursued: The sand and cement, in proper proportions, are weighed out and thoroughly mixed dry on the mixing slab, then the process is the same as described for the neat briquettes.

In determining the proper percentage of water for sand briquettes, the following formula is used:

$$E = \tfrac{2}{3}NA + 60,$$

where, $N =$ weight (in grammes) of water required for 1000 grammes of neat cement

$A =$ weight of cement (in kilogrammes) in 1000 grammes of the sand mixture

$E =$ weight (in grammes) of water required for the sand mixture.

A table has been prepared based on this formula, as modified by experience, giving the proper percentage of water to be used for different proportions of sand. This has been found not only to produce more uniform results, but also to greatly facilitate the work of mixing. The standard proportions are one of cement to two of sand for natural cement, and one of cement to three of sand for Portland cement.

Standard Sand.—The sand is crushed quartz, all of which passes a No. 20 sieve and is retained on a No. 30 sieve.

Mixing and moulding by hand has been found to produce more uniform results than can be obtained with any of the machines now in use. Besides, the mass being under perfect control, the proper consistency is reached more quickly, and can be told at once by an experienced person by its appearance and peculiar feeling.

In mechanical mixing machines similar to Faija's, the cement has a tendency to ball, especially if a quick setting one, incipient setting often taking place during the removal of the mass from the mixer, which necessitates retempering before moulding can be attempted.

The Boehme hammer requires about three minutes to mould each briquette or about one-half hour to mould ten, whereas the same number can be moulded by hand in about fifteen minutes. Comparative tests have shown that briquettes moulded by hand give higher results and nearly as uniform as those made by the Boehme hammer apparatus.

In France and Germany, it is the rule to mix slow setting cements three minutes, and quick setting ones one minute before moulding. Experience in this laboratory has been that greater uniformity in the results is obtained by mixing to the proper consistency and moulding as quickly as possible. The aim being to have the cement in the mould before incipient setting commences.

The briquettes, prior to their immersion in water, are kept in moist air for a period of twenty-four hours, except in the case of the twenty-four hour tests, in which they are immersed after hard set.

Moist Closet.—For this purpose there has been designed a moist closet (Figs. 11 and 12), which has replaced the old method of covering briquettes with a damp cloth. This closet, which is made of soapstone 1¼ inches thick, is supported by a wooden frame and is 3 feet long, 2 feet high, and 18 inches wide. Along the front is a strip of soapstone, 3 inches wide, forming a basin of the bottom of the closet in which the water is placed for keeping the air moist. The doors are made of wood, covered with planished sheet copper,

and are rabbetted to fit tightly. There are two sets of shelves, the lower being a wooden rack, and the upper is formed of strips of plate glass, 33 inches long, 3 inches wide. When closed, the closet is perfectly tight, the water in the bottom keeping the air moist, preventing the briquettes from drying out, and thus checking the process of setting.

This apparatus, aside from its obvious convenience, possesses marked advantages over the old method. The cloth could never be made or kept uniformly damp, it dried out unequally, which rendered it impossible to submit all briquettes to the uniform treatment that can be obtained in the moist closet.

Briquettes which have been removed from the moulds are placed on edge on the glass shelves, while the moulds containing the briquettes too soft to be removed are placed on the rack.

Numbering.—The number of the sample is marked on each briquette; each group of briquettes after the first group being indicated by an additional letter, thus the series of neat briquettes are marked: 2098; mortar 1 to 2, 2098A; mortar 1 to 5, 2098B; etc.

A thin layer of neat cement is spread over one end of briquettes containing four or more parts of sand, to make a smooth surface for numbering on.

IMMERSION.—*Tanks.*—For preseving the briquettes in water, small agate pans were formerly used, which have now been replaced by large soapstone tanks, six in number, each 7 feet long, 2½ feet wide, and 7 inches deep, outside measure, having a capacity for over 10,000 briquettes. There are at the present time in these tanks about 4,000 briquettes of various ages from four years down. These tanks are shown in detail in Fig. 13.

They are supported by two frames, formed of steel shapes. Each tank is supplied with a continuous stream of water, at a temperature never less than 70° F., which enters at one end near the bottom through two pipes, and overflows through two pipes at the other end, the pipes being so arranged that the water flows uniformly through the tanks. The rate of the flow through the tanks is controlled by a valve on each supply pipe. The main feed pipe is supplied with hot and cold water, from pipes provided with valves, by which the temperature of the mixture is regulated.

The tanks were made of soapstone because it is non-absorptive, non-corrosive, and easily cleaned. The water is previously filtered before entering the tanks, and is always clean and pure. It has been the experience in the laboratory, that where briquettes are immersed in pans the water becomes strongly alkaline unless

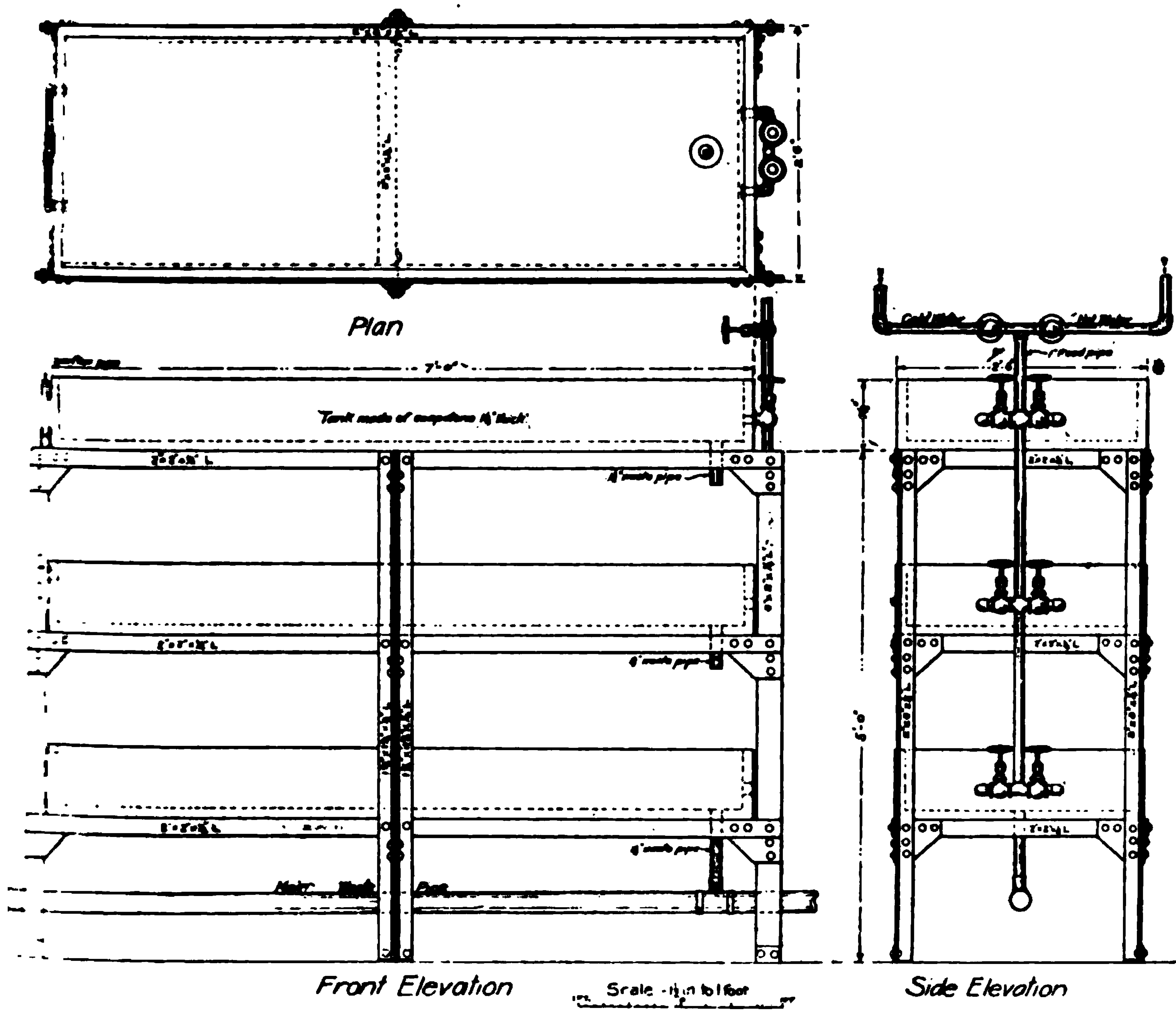


FIG. 13.—DETAILS OF THE IMMERSION TANKS.

it is frequently changed and the pans cleaned. Inasmuch as these tanks have replaced three dozen small pans (22 inches x 15 inches x 3 inches) it is evident that besides the advantages of having all briquettes immersed under perfectly uniform conditions, a very great amount of time and labor is saved.

The briquettes are immersed on edge, and placed a slight dis-

tance apart so as to permit the free circulation of water around them. On the outside of the tank opposite each row, celluloid cards are glued, on which are marked in pencil the inclusive numbers of the row. The briquettes being arranged in the tanks in consecutive order, they are easily located.

TIME OF SETTING.—For determining the time of setting, the laboratory is provided with a Vicat needle and Gilmore's wires.

Vicat Needle.—The Vicat needle illustrated in Fig. 1, consists of a frame *K*, bearing the movable rod *L*, having the cap *D* at one end and the needle *H* having a circular cross-section of one square millimetre at the other. The screw *F* holds the needle in any desired position. The rod carries an indicator which moves over a scale (graduated to centimetres) borne by the frame *K*. The rod with the needle and cap weighs 300 grammes; the paste is held by a conical hard rubber ring *I*, 7 cm. in diameter at base, 4 cm. high, resting on the glass plate *J*, 15 cm. square.

To determine if the paste is of normal consistency, the needle *H* and cap *D* are replaced by the rod *B* (1 cm. in diameter) and the cap *A*. The rod *L* then weighing 300 grammes shall stop sinking 6 mm. from the bottom of the ring, 4 cm. deep, filled with paste.

For neat pastes the setting is said to have commenced when the polished steel needle weighing 300 grammes does not completely traverse the mass of normal consistency, confined in the rubber ring, and the setting is said to be terminated when the same needle gently applied to the upper surface of the mass does not sink visibly into it.

A thermometer *C* graduated to $\frac{1}{5}$° C. is stuck into the mass and the increase of temperature of mass during setting can be thus observed. The paste is kept in the moist closet during the operation, being removed only to make trial tests of the setting.

This is the apparatus adopted by the French Commission* and the Society of German Cement Manufacturers.

Gilmore's Wires.—Gilmore's wires are commonly used in this country for determining the time of setting. They consist of two brass balls (Fig. 2), each bearing a wire having a circular section.

* Commission des Méthodes d'Essai des Matériaux de Construction.

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 3, November, 1896.]

"Hot Water" Apparatus. Mixing Table. Testing Machine. Weighing Table.

Fig. 14.—View of the Cement Laboratory.

The apparatus will stop automatically at the end of a fixed number of revolutions of the driving mechanism.

SPECIFIC GRAVITY.—The specific gravity has replaced the old weight per bushel test.

There are two forms of apparatus in the Laboratory: one according to Candlot (Fig. 4), and the other according to Le Chatelier (Fig. 3).

Candlot's Apparatus.—Candlot's apparatus (Fig. 4) consists of a graduated tube *B*, terminated by a bulb *A*, which fits tightly on the ground neck of a flask *D*. The liquid used in making the determinations is introduced in the tube *B* in sufficient quantity to bring the level of the liquid above the zero point, when the tube is reinverted on the flask *D*.

A record is made of this height and the liquid is returned to the bulb *A*, the flask *D* is removed, into which a known weight (usually 100 grammes) of cement is introduced. The flask *D* is again connected with the tube *B*, and the whole is agitated to expel the air bubbles. The new height of the liquid is read, and the difference between this and the former reading is the volume displaced by the known quantity of cement.

The connection is rubbed with vaseline to render it tight, but even then, unless the operator is very careful, the consequent losses affect the accuracy of the results. This apparatus has been abandoned for the more convenient and precise form of Le Chatelier.

Le Chatelier's Apparatus.—This apparatus consists of a flask *D* (Fig. 3) of 120 c.cm. capacity, the neck of which is about 20 cm. long. In the middle of this neck is a bulb *c*, above and below which are two marks engraved on the neck; the volume between these marks *E* and *F* being exactly 20 c.cm.. Above the bulb the neck is graduated into $\frac{1}{10}$ c.cm. The neck has a diameter of 9 mm. Benzine being free from water and being neither very volatile nor hygroscopic, is used in making the determinations.

The specific gravity can be determined in two ways:

(1) The flask is filled with benzine to the lower mark *E*, and 64 grammes of powder are weighed out; the powder is carefully introduced into the flask by the aid of the funnel *B*. The stem

of this funnel descends into the neck of the flask to a point a short distant below the upper mark. The cement cannot stick to the sides of the neck and obstruct its passage. As the level of the benzine approaches the upper mark, the powder is introduced carefully and in small quantities at a time, until the upper mark is reached. The difference between the weight of the cement remaining and the weight of the original quantity (64 grammes) is the volume which has displaced 20 c.cm.

(2) The whole quantity of cement is introduced and the level of the benzine rises to some division of the graduated neck; this reading + 20 c.cm. is the volume displaced by 64 grammes of cement. The specific gravity is then obtained from the formula:

$$Sp.\ G. = \frac{\text{Weight in air.}}{\text{Displaced weight or loss of weight in water.}}$$

The flask during the operation is kept immersed in water in a jar *A*, in order to avoid any possible error due to variations in the temperature of the benzine. The cement in falling through the long tube completely frees itself from all air bubbles. The results obtained agree within .02.

HOT WATER TESTS—*Apparatus.*—Fig. 15 shows in detail what is commonly used for the "hot water" or "boiling tests." It serves a dual purpose in this Laboratory:—(1) It is used in the determination of the specific gravity and absorption of blocks of stone, bricks, concrete, etc., and (2) for seeking evidence of unsoundness in cements.

It consists of two tanks, made of 22 ounces copper, and placed one within the other, the inner tank being supported by three yellow pine cantlings (3 inches × 1½ inches) running the length of the tank. These are supported by a frame formed of steel shapes. The cover *S*, provided with steam vents and an opening for the insertion of a thermometer *T*, is made of two sheets of copper, separated by a one inch layer of hair felt, and fits tightly into the inner tank. The cover is supported and counterbalanced by means of the weights and pulley *W*, *P*, attached to the upper frame.

Both tanks are filled with water to the heights shown, the levels being maintained by bottles *B*, which automatically supply the loss due to evaporation or other causes. The inner tank is pro-

vided with two sets of shelves of tinned copper wire cloth with a one inch mesh, supported by heavy copper angles; the lower shelf is always submerged and covers the whole area of the tank, while the upper shelf covers one-half this area and is always in the stream.

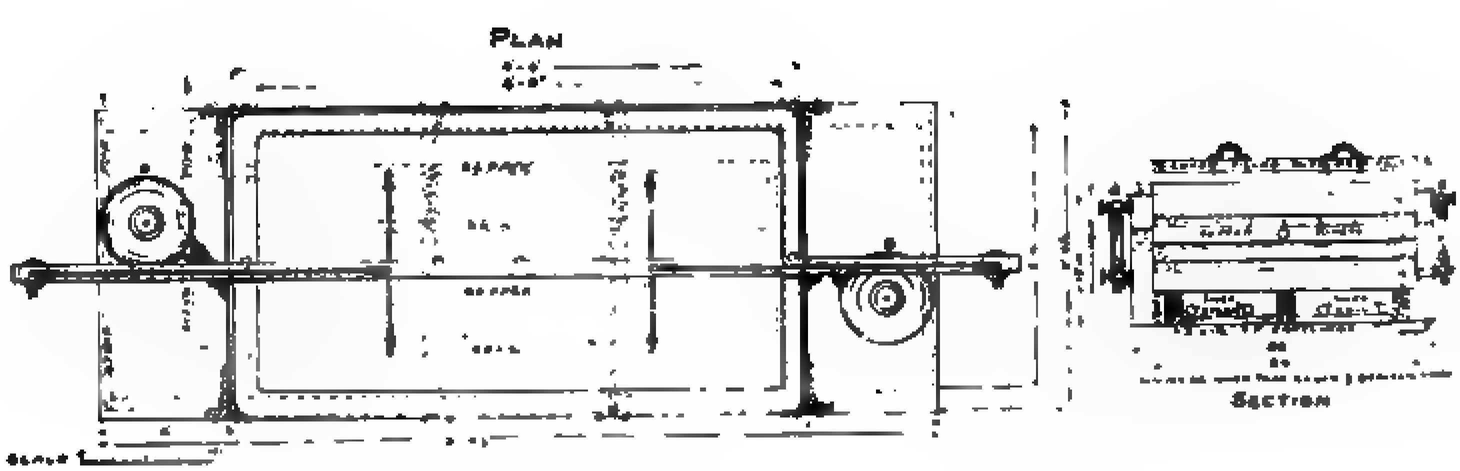


FIG. 15.—DETAILS OF THE "HOT WATER" APPARATUS.

The tanks are heated by means of a copper coil supplied with steam, at about 80 pounds pressure, from a one inch pipe. The water in the tanks (about 30 gallons) can be raised to boiling in about 3 minutes. The temperature of the water in the inner tank is controlled by means of a regulator, which can be set and con-

briquettes are taken as the tensile strength; in important tests, however, the average of five briquettes is taken.

Testing Machines.—For determining the tensile strength, the Laboratory possesses a Riehlé and a Fairbanks Cement Testing Machine, each of 1,000 pounds capacity. These types of lever machines are too well known to merit special description. While the Fairbanks machine is used on account of its being more nearly automatic, neither of these machines fully satisfy the requirements of the Laboratory.

Plans have been prepared for an entirely automatic cement testing machine of 2,000 pounds capacity based on a different principle, in which it is hoped that the faults of the present types of testing machines will be corrected. I hope to be able to describe to the Club at some future time both this machine and the automatic sieving device.

Conclusion.—A great deal of attention is paid to the results of the tests of mortar taken from a mixing-box. The briquettes are made from the actual mortar on the work, (1) as soon as mixed, and (2) just before it goes into the work. Experience has shown this to be one of the best aids in judging the actual merits of any brand of cement. Concrete cubes are also made on the work, and their weight per cubic foot and crushing strength is determined, the crushing strength giving an excellent idea of the adhesiveness of any brand of cement.

All cements are from time to time submitted to a chemical analysis. For this purpose the chemical laboratory (Figs. 12, 16 and 17) has been equipped with every facility for making complete chemical analyses. The detail apparatus is such as will be found in any well equipped laboratory, and does not require further description.

In addition to the regular tests, a great deal of experimental work is being carried on. Among the many studies may be mentioned the strength of cement in air, in hot water, mixed with various adulterants, and with various proportions of different sands.

Besides the standard sand the laboratory is provided with German normal and various kinds of natural sands.

The temperature of the laboratories is usually between 60° and

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Reagent Closet. Apparatus Closet. Working Table. Hood. Table for Distillations, etc.

Fig. 16.—View of the Chemical Laboratory.

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 3, November, 1896.]

Sink. Working Table. Microscope. Balance. Reagent Closet.

Fig. 17.—View of the Chemical Laboratory.

70° F. It is never permitted to fall below 60° F.; this being regulated by steam heat. In summer the windows are kept closed, and the temperature rarely rises above 80° F.

At the end of each year the results of the year's tests are averaged, each brand of cement being rated according to this average. The requirements of the specifications for the ensuing year being fixed in accordance with these results. The gradual increase in the average tests and requirements each year is well illustrated by the diagrams Fig. 18.

FIG. 18.—AVERAGE TESTS AND REQUIREMENTS.

While the city requirements are to-day higher than those of any other city, nevertheless they are considerably less than the average results of the tests for the year 1895. This general increase in the requirements can be ascribed to three causes: increased skill in testing; gradual weeding out of inferior brands of cement, and to the improvements in the quality of the cement, due to the improvements in the process of manufacture.

The city of Philadelphia, as a direct result of maintaining this

laboratory, is using cement from 30 to 50 per cent. stronger, and at a cost of from 20 to 40 cents per barrel less, than it was in 1892. The city consumes approximately each year about 100,000 barrels of natural cement, and 30,000 barrels of Portland cement. It can be safely assumed on the basis of the prices prevalent in 1892 (when the laboratory was permanently established), and those prevalent to-day, that the city has saved in the last four years over $70,000. The cost of maintenance, exclusive of salary during this time, has been less than $500 per year. In other words, the city has saved $70,000, at a cost of less than 10 per cent. by the maintenance of this laboratory.

In closing, I wish to state that the successful development of this laboratory has, in a great measure, been due to the energetic support given to it by Mr. George S. Webster, Chief Engineer, Bureau of Surveys.

DISCUSSION.

Mr. F. H. Lewis.—I congratulate Mr. Humphrey on having been provided by the city with a good laboratory. The cement laboratory of the Bureau of Surveys was the first engineers' laboratory for cements established in the city and there is no doubt that it has done more to reduce our local "factor of ignorance" on this subject than any other agency. The results which Mr. Humphrey reports are received everywhere with very high regard. They are widely quoted by manufacturers, and nobody has ventured to question the entire accuracy or fairness with which the work is done.

The question of chemistry in connection with cement tests has been receiving much attention lately, without yet, I think, being used to much advantage. We find in nearly all dealers' circulars, analyses of their cements, and such analyses are asked for more and more by engineers, yet comparatively little use is made of them as criteria of quality.

It has occurred to me that the significance of these chemical results could be, perhaps, elucidated a little.

The following analysis is taken from a printed pamphlet issued by a cement company: Analysis No. 5.—SiO_2, 21.14; Al_2O_3, 6.30; CaO, 66.04; MgO, 1.11. I suppose it is published

with the idea that it shows the good quality of the product, but as a matter of fact it does not; the reason is apparently obscure, but actually not very difficult to see, as I shall endeavor to show.

Here is a second analysis which appears in a cement circular and which is perhaps a better example than the other since the line is not apparently too high; nevertheless, there is too much, and this analysis is practically on a par with the other. Analysis No. 6.—SiO_2, 19.67; Al_2O_3, 6.93; CaO, 62.79; MgO, 1.72.

There have been two formulas proposed for determining the proper constitution of cements. They are based on the fact that cement mortar is essentially a combination of two acids with two alkalies; hence, if we know what proportions they combine in, we can tell whether the chemical equivalents of the acids are sufficient to combine with the equivalents of the alkalies. Vicat, who first commenced to study cements scientifically in Europe, proposed a formula like this: $\frac{Al_2O_3+SiO_2}{CaO+MgO}$ = hydraulic index. I am not sure whether he placed the magnesia in the denominator or not, but it ought to be there. This ratio he called the hydraulic index, and I have recently had occasion to note its use for the first time in cement specifications in the United States. This specification recently appeared in the city of Brooklyn for a large amount of cement, and the index was fixed at 45 per cent. Vicat intended to classify cements by their hydraulic index as feebly hydraulic, hydraulic limes and hydraulic cements. The hydraulic index, however, has been used since then to define the proper relations of acids to alkalies.

The second formula was brought forward by Le Chatelier in an experimental research on the constitution of mortars, which is as fine a specimen of the scientific method as ever appeared. He showed that were three silicates of lime, of which only one, $SiO_2\,3CaO$, was susceptible of taking set by the addition of water, and while there were several aluminates of lime, the only one likely to exist in Portland cement was $Al_2O_3\,3CaO$. From this he reached the conclusion that, by chemical equivalents, the lime plus the magnesia divided by the silica plus the alumina, must be less than 3; in other words three equivalents of alkalies to one of acids was the maximum ratio indicated by theory and that in

practice the figures must always be less and indeed seldom exceeded 2.7. We accordingly have these two formulas:—

$$\text{Hydraulic index} = \frac{Al_2O_3 + SiO_2}{Ca\,O + MgO} = \text{say 44 per cent.}$$

and

$$\text{Le Chatelier's ratio} = \frac{Ca\,O + Mg\,O}{Si\,O_2 + Al_2\,O_3} = \text{less than 2.7 by equivalents.}$$

I have carefully followed these formulas through a large number of analyses and the results are quite satisfactory; surprisingly so. I do not pretend that it is practical by the use of these formulas to say from the analysis whether the cement must necessarily be unsafe or not. In dealing with chemistry we must use it to explain facts rather than to demonstrate anything directly. But this way of dealing with analyses will always enable us to form a valuable opinion on the product submitted and to follow our physical tests more carefully as we find the ratios to be unsatisfactory. To illustrate more fully the point in the case I give below a table showing the two analyses quoted above, and also some others. Analyses 5, 6 and 7 I have taken just as I found them as examples of the point I wish to make; it is quite possible that these analyses and not the cements are wrong.

SPECIMEN ANALYSIS OF CEMENTS WITH HYDRAULIC INDEX AND LE CHATELIER'S RATIO CALCULATED.

No.	SiO_2	$Al_2\,O_3$	CaO	MgO	*Hydraulic Index.*	*Le Chatelier's Ratio.*
			NORMAL CEMENTS.			
1	21.38	8.97	60.82	1.35	49	2.5
2	23.55	7.47	62.00	1.42	50	2.45
3	23.87	6.71	64.49	1.04	47	2.5
			PUBLISHED ANALYSES WHICH ARE NOT NORMAL.			
5	21.14	6.30	66.04	1.11	41	2.9
6	19.67	6.93	62.79	1.72	41	2.9
7	19.50	8.24	63.26	1.28	42	2.8

		LIME HIGH, BUT IN SATISFACTORY PROPORTION.				
8	23.50	7.75	64.07	0.58	48	2.5
9	24.85	6.07	64.40	1 26	47	2.5
10	24.30	5.33	64 12	0.72	46	2.5
		LOWER LIME, BUT NOT SO GOOD.				
11	21.60	6.30	62.72	0.98	44	2.7
12	19.80	6.73	63.27	2 02	41	2.9
6	19.67	6.93	62.79	1.72	41	2.9

MR. LESLEY.—The laboratory at Zurich seems to be the leading one of the world, and is a very large building wherein may be tested all building materials, including iron, wire, wood, stone, brick and cement. The cement testing department is one of the leading departments in the laboratory; the principal thing noticeable was, that mechanical power was used for nearly every purpose. In Paris and at Havre, the apparatus are all of very excellent character, but operated by hand. Everything that goes into these large pieces of engineering work, such as bridges, reservoirs, aqueducts or buildings, is tested as it leaves the quarry, machine shop, furnace or mill, the test pieces being taken from the material completed and ready for use in the work. On the other hand, cement goes to the consumer in the shape of a powder, and is made into test-pieces by some one on the work; or in other words the finished product is tested after the personal equation of some one other than the manufacturer of the article itself, has entered into the problem of testing. This is rather a serious matter to the cement manufacturer; when the briquettes are put upon the testing machine the manufacturer must stand the possible errors of the man who makes his product into the final test pieces. It is for this reason that we are all glad to see the tendency toward the establishment of city laboratories, such as the excellent one of the city of Philadelphia, where there can be careful, accurate, impartial and fair testing.

There is another matter which the paper of this evening brings to my mind, and that is, the statement as to the increased results in the tensile strains that have been arrived at since the establish-

ment of the testing laboratory by the city of Philadelphia. In this connection, while Mr. Humphrey's paper goes back, I think, only to 1891, the results are even more remarkable if an examination is made of the records of the city of Philadelphia as far back as 1885 or 1886. At that time the requirements for natural cement were very low, and the cement in neat mortar at seven days ran barely to forty or fifty pounds. A demand was made for a better grade of cement. The manufacturers undertook to produce such a quality, by adding to the burned material out of which natural cement is produced, Portland cement clinker in certain proportions, making "Improved" natural cement. The effect was to increase the neat results to seventy or eighty pounds at seven days, and give a cement which in sand mortars, 2 to 1, would run thirty or forty pounds at seven days, or nearly as high as the former neat cement tests showed. Since then, the specifications for natural cement have been increased both in neat and in sand mortars, and now require in 2 to 1, sand and cement, 120 pounds, or nearly three times as strong as the neat cement gave at similar periods before the change was made from natural to "Improved" natural cements in this market, and this increase in strength has been made without any increase in the price of the cement. For this reason, I think, the city owes a great deal to the testing laboratory, and to those who in the interest of the good work have constantly held the manufacturers up to the highest standards of quality in their product.

Mr. Christie.—The relation between chemical analysis and physical properties of cements, as of many other materials, is a baffling and perplexing question. Sometimes the analysis may possibly be incomplete, and we may miss components that exert important influence, or the varying influence of changes in the ratio of the components may be bewildering in an investigation of this character. Our knowledge is too imperfect to express a judgment until such a time as a large mass of data is collected and thoroughly studied. Meanwhile no investigation of materials is complete unless physical tests are accompanied by chemical analysis. So far as the method of testing is concerned, why is there not more dependence placed on transverse tests of cement than on either tensile or compressive tests? Experience

with material of a granular character, or of low ductility, generally indicates that a better estimate of its utility can be derived from transverse tests than by other methods. No matter how carefully the specimens and their attachments are prepared, the strains applied either for tension or compression are apt to be unequally distributed through the material, or accompanied by cross-breaking strains; but with transverse tests on material prepared of a definite length and definite cross-section, the liability to inaccurate results is less.

MR. HUMPHREY.—In reply to Mr. Christie I desire to say that while it might be possible to obtain more accurate results from the transverse test, it would be much more difficult to prepare the test bars, which must be of uniform density, and at least 6 inches long. This seems to be the opinion of the French Commission, who considered this subject without reaching final conclusions. I think the tensile tests give practically all the information we need, since the sand test furnishes an idea of the adhesiveness of a cement, which is the property brought into play in all work into which cement enters.

PROF. PORTER.—The great trouble in cement testing, so far as tensile strength is concerned, is the lack of uniformity in results, owing to the personal equation of the manipulator. For example, I recently took a sample of cement from a shipment, tested it and found that it failed to comply with the specified tensile strength. The contractor was notified and he, in turn, informed the manufacturers. The latter requested that their representative be allowed to make a test. This request was granted and the result was about 80 per cent. of that first obtained. The manufacturers then suggested a test being made by a representative from a certain testing laboratory. This was also granted, and the result was about 50 per cent. in excess of the first test and brought the cement up to the requirements. All these tests were made in the same laboratory, using the same amount of water, same sand, mixed and moulded according to the manipulator's understanding of the method proposed by the American Society of Civil Engineers, and the briquettes were broken on the same machine by the same operator.

Again, I took another sample of cement, divided it into ten

parts and sent them to as many persons engaged in testing, with a request that they make a seven-day tensile test, according to their understanding of the method proposed by the American Society of Civil Engineers, and return the broken briquettes with their report. I had nine replies and nine different results, varying from 75 to 247 pounds, and then I knew just as much about the cement, or a little less, than I did before. Some of the briquettes were very porous, while others were extremely dense. Herein is the personal equation of the manipulator. Tensile strength requirements in cement specifications have therefore no meaning unless weighted by this personal equation.

Mr. Humphrey.—I believe that in testing cements, the highest result is nearer its true strength than the lowest. You cannot get any more strength from a cement than there is in it. In the tests in the city laboratory, as far as uniformity goes, the briquettes break almost at the same figures, and usually do not vary more than ten pounds. I do not believe it possible to have a "standard specification;" it is practicable and very necessary to adopt "standard methods," but when you deal with a material in which the chemical constitution may vary from day to day, I do not believe it possible to obtain standard results from it.

Prof. Porter.—Regarding values given in cement specifications, I would cite another instance. I had a man in my employ who made all my cement tests, and I based my specifications on his results. I now have another man who can only obtain about two-thirds as much as the first one, so I must drop my specifications to this latter man's figures, or abandon any requirement for tensile strength, as I have decided to do. I make tensile tests, but only as a check on the uniformity of the shipments.

Mr. Lesley.—Professor Porter's experience is very similar to the experience I am constantly meeting in our business, and in many cases the problem that arises, is not so much the requirements that are to be exacted from the cement, as the knowledge of the conditions under which these requirements are sought to be obtained. The personal equation of the laboratory and of the operator is a very material matter. In one case we had the contract for the cement on a very large piece of railroad construction; the cement had only arrived on the work, when it was

condemned. The tester was not familiar with the business and a man was sent up to educate him; he soon acquired the knack of testing. Subsequently the operator resigned and a new tester was put on; the tensile strain of the cement went down to zero. This tester gradually became familiar with the work, and the cement gave the same result on his piece of work as it was giving on the other part of the road in the laboratory of the railroad. Subsequently there was a new tester, and again the same results followed. From that time on there were no changes in the testing department, and everything went along satisfactorily.

An interesting experiment is going on in Chicago toward the elimination of the personal equation of the individual making briquettes. In the laboratory of the Chicago Drainage Commission, where a large number of briquettes are made every day, one man opens the sample boxes and empties the sample of cement, another man weighs the cement and water, another man mixes up the mortar, another man makes the briquettes and another smoothes them off and takes them from the mould, and finally, a sixth man breaks the briquette. Two testing machines are used in this laboratory, one a Riehlé and the other a Fairbanks, and the results of the two tests are very uniform.

MR. J. F. ROBESON.—There has been a good deal of very interesting talk in regard to the physical characteristics of cement. Looking at the matter from a chemical standpoint, Mr. Lewis has written a formula on the board in which the denominator is $CaO + MgO$. I can hardly think that he means that MgO could replace CaO entirely, and I should like to ask him to what extent this replacement may go, and also whether there are any specifications in use now which required any certain low percentage of lime or magnesia.

MR. LEWIS.—Magnesia is supposed to replace lime; if it does not it is very unfortunate. Magnesia has always been regarded as undesirable in cement; that is, it has been considered desirable to keep it as low as possible. The German Society has been investigating it for three years and will not report before 1898. In this country we have never given it much attention, as we did not suppose it was necessary; but we are finding more magnesia in raw materials than formerly, and every one is now giving it

some attention without being able yet to say much about it. I would like to ask Mr. Humphrey whether he has included the boiling test in his specifications, and whether he has developed anything new on the subject.

Mr. Humphrey.—The City does not specify definite requirements for the "hot water test" in its cement specifications. The "hot water" apparatus has been installed in the laboratory under the firm belief that good results can be obtained with it, and that it is a valuable safeguard. We are now making experiments with it and when the results assume definite shape, from which logical conclusions can be drawn, I shall endeavor to pre-

Fig. 19.—Cement Testing Machine.

sent them to the Club, but in their present indefinite state I do not feel that I ought to present any half-digested information.

The President.—Mr. Humphrey mentioned some defect in the two testing machines; what were these troubles?

Mr. Humphrey.—In the Fairbanks or shot machine, Fig. 19, which is the type used in the Laboratory, the briquette is placed in the jaws *N* and the adjusting wheel *P* is turned until the jaws are in bearing on the briquette and the lever *D* is in contact with the stop *K*. A valve in the hopper *B* is then opened and the shot enters the pan *F*, through the outlet *I*. The rapidity with which the shot enters the pan *F* can be regulated. The weight

in the pan *F* increases and with it the strain on the briquette, until the latter breaks, and the lever *D* falls and shuts off the flow of shot. The pan *F* is then removed and hung on the hook *E* and weighed by means of the sliding weight *R*, the counterweight *G* and the weights *H*. This weight is the tensile strength in pounds per area of the section of the briquette. Should the briquette be distorted, which is not unusual, the jaws slip in consequence of not being in perfect bearing, and the lever *D* falls and shuts off the flow of shot before the briquette is ruptured. It is then necessary to partially relieve the strain on the briquette, raise the lever *D* by tightening the wheel *P* and again start the flow of the shot. This can be avoided by applying a greater initial stress before opening the valve of the hopper *B*, by tightening the wheel *P*. A skillful operator knows about how much initial stress to apply. This prevents the machine from being entirely automatic, and is the principal objection.

Mr. Furber.—Referring to Mr. Leslie's remarks on the testing of cement away from the point of manufacture, differing in this respect from the testing of other building materials, such as iron, steel, brick, stone, etc., it might be said, that the conditions demand such treatment in the case of cement or other similar perishable materials. Iron, steel, etc., when tested stay "tested," but we are not willing to accept the testimony of the character of cement from the barrel head. I should like to ask Mr. Humphrey if after eliminating the sources of error which he points out, he considers the Fairbanks' "shot" machine a reliable one for testing neat briquettes. In my experience, while I have not tested as many briquettes as Mr. Humphrey, I have found a remarkable difference between tests given by the shot machine and long lever machine. The results obtained from the tests for tensile strength on a number of briquettes with the "shot" machine, caused me to doubt the reliability of the Fairbanks machine, and as much higher results were obtained from the Riehlé or Olsen long lever machines, I became somewhat skeptical of the results given by "shot" machines.

Mr. Humphrey.—I believe the operator should be familiar with either type of machine. The shot machine is essentially the machine used by the French and Germans, although it is

much more clumsy in shape. We have both the Fairbanks and the Riehlé machines in the laboratory, and find that the former machine gives more uniform results. I have prepared plans for a machine which it is hoped will overcome the objections to the present types of cement testing machines, and prove to be the best yet devised.

PROF. PORTER.—All three of the makes of machines mentioned by Mr. Furber, are in the Department of Civil Engineering at Lafayette College. We have modified the Olsen, making we believe the "best machine in the market."

MR. HUMPHREY.—I would like to ask Prof. Porter, if, in the machine just described, there is not an irregular motion in the weighing bar,—that is, the weighing load is not applied smoothly and uniformly, but in short jerks?

PROF. PORTER.—We have no trouble in keeping the needle-bar floating when the machine is working automatically, but it raises on slight jerks. The poise moves with about the same degree of uniformity as when worked by hand.

MR. TINIUS OLSEN (*Visitor*).—I have not done much in cement testing, and can therefore not say much about the same, my business having been confined mostly to making the apparatus for cement testing. I believe the poise on the beam of the testing machine should be run out regularly, say at 300, 400 or 500 pounds per minute, as may be desired, and the strain applied to keep the beam in equipoise until the specimen breaks. We have made a couple of machines so arranged—one for the Pennsylvania University and one for the Drexel Institute, and are now making another which is still further improved.

MR. LITTLE.—I made some tests of natural cements for the city in 1883, and could only get from 6 to 8 pounds, tensile strain, in twenty-four hours. I do not remember the results of the seven days' test. The manufacturers were consulted and agreed to furnish an "*improved*" cement that would stand 50 pounds in twenty-four hours. Since that time there has been a gradual increase in strength as shown by the tests.

MR. HUMPHREY (*Communicated*).—Mr. Lewis' statements, concerning the chemical relations in cement, while they may prove to be valuable checks, taken in conjunction with the physical

tests cannot be followed too rigidly. The limits of the hydraulic index referred to have been differently quoted by authorities on cement, and range from 40 per cent. to 70 per cent. In Spaulding's notes on "Hydraulic Cement" he states that "the hydraulic index in a Portland cement of normal composition varies from 42 per cent. to 50 per cent." Le Chatelier, in his paper before the Engineers' Congress, Chicago, 1893, gives two formulæ:

$$(1) \qquad \frac{Ca\ O}{Si\ O_2 - Al_2\ O_3 - Fe_2\ O_3} > 3.$$

$$(2) \qquad \frac{Ca\ O}{Si\ O_2 + Al_2\ O_3 - Fe_2\ O_3} < 3.$$

in which $Ca\ O, Mg\ O$ (which is added to the lime) $Si\ O_2, Al_2 O_3$, and $Fe_2 O_3$ represent the number of equivalents of these substances present. He states, that, "in a Portland cement of normal composition the proportion of lime, according to the chemical formulæ of the compound, should be greater than that determined by formula (1)" "and less than that determined by formula (2)." "It is necessary by reason of the inevitable imperfection of the mixture to keep well below this limit (formula 2), beyond which there will remain uncombined lime. Notwithstanding the care bestowed upon the burning of Portland cements, it is very seldom that they do not contain a small quantity of free lime."

Mr. Lewis, in his quotation of the formula (2), and in his tabulated analyses, has not considered the percentage of iron present ($Fe_2\ O_3$), which, as will be seen later, materially affects the values obtained by the formulas.

The following are two analyses of Portland cements:

No. 1.		Vicat's Formula.	Le Chatelier's Formulas. (1)	(2)	Lewis Le Chatelier.	No. 2.	Vicat's Formula.	Le Chatelier's Formulas. (1)	(2)	Lewis Le Chatelier.
$Si\ O_2$	20.99					21.08				
$Al_2\ O_3$	4.12					5.78				
$Fe_2\ O_3$	5.18	41.1%	3.9	3.1	2.8	4.89	40.7%	4.5	3.2	2.9
$Ca\ O$	60.75					64.27				
$Mg\ O$	0.41					1.66				

Analysis No. 1 shows the cement to be low in lime, yet it is an unsatisfactory one according to Le Chatelier's formula; while according to Mr. Lewis, this cement would meet the formula, as it gives a result of 2.8.

Analysis No. 2 is high in lime and as poor an example as any quoted by Mr. Lewis. The cement of which No. 2 is an analysis has been in the work for over three years, and as yet does not show the slightest signs of unsoundness. I have also carefully observed other cements which gave equally unsatisfactory results by these formulas, and have failed to find evidence of unsoundness. We study the chemical relations in the City Laboratory, yet we do not deem it advisable to burden the specifications with clauses of questionable value. While deductions from these formulas may prove true of most cement analyses, nevertheless it is yet to be demonstrated that cements which fail are of bad quality, and vice versa.

Concerning Professor Porter's remarks on the value of tensile requirements in specifications, I wish to say that the requirements should be based not upon the results which others have obtained, but upon the results which it is practicable to obtain under actual conditions. An engineer before preparing a specification for cement should first determine what tests he, or the person who will do the testing, can obtain from recognized high-grade cements. Upon the results of these tests he should base the requirements of his specifications. If such methods were pursued, engineers would be spared the embarrassment (after finding it impossible to secure a cement which will meet the requirements) of being compelled, either to use cement regardless of the tests, or to lower the requirements, which have been arbitrarily adopted without regard to their ability to obtain the required tests.

If engineers and manufacturers would direct their efforts to securing "standard methods," they would soon realize the futility of demanding "standard specifications." Methods of testing may be systematized and made more uniform, but as long as the results depend upon the "personal equation" of the person making the tests, there can be no "universal" or "standard specification." Assuming that a "standard specification" was

adopted, it would be either too low to be effective, should the tests be made by experts (because they would be able to obtain the required tests from cements of inferior quality), or it would be so high that unskilled persons would not be able to obtain the required tests from cements of the highest quality,—granting that the methods were identical in both cases. When cement can be tested mechanically, to the exclusion of all "personal equation," then we may hope to have a "standard specification" adopted.

X.

ELECTRICITY IN GOLD MILLING.

By H. M. Chance, Active Member of the Club.

Read October 17, 1896.

That electricity can be applied in some way to effect the rapid, complete and economic extraction of gold from the ores or materials with which it is associated, is a belief, amounting almost to a conviction among mining men, and which is also prevalent among mining engineers. In the following paper I have attempted a classification of the numerous methods by which it has been proposed to use electricity for this purpose.

Evidence of the interest which this use of electricity has created, is found in the large number of patented and unpatented inventions claiming the use of electricity in milling and reducing processes, and in the readiness of the engineer, mine manager and mine owner alike to give respectful attention to the claims put forth by the inventors of these processes. The inventors of such processes and appliances have found ready listeners, and have been able to secure the expenditure of considerable sums for the construction of apparatus and for experimenting with their various appliances.

The proposed processes for using electricity in treating gold ores or gold-bearing materials may be divided into six distinct classes, each employing or embodying a different principle or method of using the current.

(1) Electro-magnetic.
(2) Electro-solvent.
(3) Electro-amalgamating.
(4) Electro-precipitating.
(5) Electro-inductional.
(6) Electro-smelting.

(1) *The Electro-magnetic* class of inventions are more generally known as "magnetic separators," and as applied to gold milling aim to mechanically separate particles of magnetic material

(such as magnetic iron ore, pyrites or metallic iron) from the grains of gold. This is one of the uses to which Edison and many other inventors first proposed to put their "magnetic separators." The idea is not new, dating back to a period before the invention of the electro-magnet. The various devices belonging to this class of inventions have not come into general or even limited use, probably because there are other equally efficient and more simple methods of effecting this separation.

(2) *The Electro-solvent* is perhaps the most fascinating of all of the proposed methods of applying electricity to the extraction of gold. It usually consists substantially of a proposition to pass a current of electricity through ore which is immersed in a solution containing a solvent of gold,—*e. g.*, cyanide of potassium, bromine or chlorine,—with the expectation of causing a rapid solution of the gold, which could then be electrically deposited upon the cathode or chemically precipitated from the solution. It has been repeatedly claimed that such methods do not require the ore to be crushed, that the electric current will cause the chemical solvent to penetrate, transfuse or osmose through the pores of large lumps of ore, and thus extract the gold by dissolving it without crushing the ore. Only the most elementary knowledge of electrolytic action is necessary to cause one to doubt the possibility of these expectations being realized. If all of the particles of gold could by any means be so electrically connected with the anode as to form practically a part of the anode plate, the desired result would doubtless be realized. As the result of all the work done in this direction seems to be without a single successful plant operating on any process included in this class of inventions, it seems exceedingly doubtful whether the electric current can be used in this way.

It may be interesting to note the reported organization of a company to use this process for the extraction of gold *in situ* by boring two series of holes into the ore or gold-bearing formation, the two series to be located some distance apart, one series to be charged with a cyanide or other gold solvent solution, and a current of electricity to be passed through the deposit from one set of bore holes to the other, with the expectation that by electrolytic transfusion, the gold solvent solution will be carried through

the intervening ore, dissolving the gold, which may then be deposited upon cathodes in the second series of bore holes, or may be extracted by pumping out the solution and chemically precipitating the gold.

(3) *The Electro-amalgamating* class of inventions includes all those processes in which the electric current is used to assist in, or to effect, the deposition of gold on amalgamated plates, or in mercury. It is perhaps the largest class of inventions aiming to use electricity in gold milling. It has been proposed to apply it to almost all forms of gold crushing, milling and concentrating machines, and almost every conceivable kind of gold-saving apparatus has been suggested as suitable for this application of electricity.

The method of application usually consists in passing a current of electricity from some part of the crushing or distributing apparatus, through the water to the amalgamating plates or to the mercury pots or troughs, the idea being that the current will aid in amalgamation, forcing the gold to unite with the mercury or amalgam.

While it is not certain that an electric current has any applicable action of this nature, the current may, if properly distributed, promote amalgamation by keeping the amalgam or mercury surfaces in good order, and it is claimed that the plates can be kept bright and untarnished for an indefinite period by this method. It seems entirely possible that polarization of the plates may effect a largely increased saving of gold in working some ores in which amalgamation is retarded or prevented by rapid "sickening" of the plates. It is also claimed that polarization of the plates facilitates the amalgamation of the so-called "rusty" gold. This claim seems worthy of careful consideration, for whether the so-called "rusty" gold owes its qualities (that is, its resistance to amalgamation) to an oxide, sulphide, telluride or other chemical film, or to an electrical or magnetic condition (as an electrostatic charge), or to allotropism, we can readily conceive that the possible effect of the electric current might be sufficient to put such gold in condition for amalgamation. Some years ago a set of electrically connected plates was put to work on the tailings from one of our most successful Western mills, and

while these tailings were supposed to contain an extremely small quantity of free gold, the return from these plates was reported to average from $200 to $300 per month. Possibly the chief difficulty in applying electric or electrolytic action to assist amalgamation in appliances used for treating free-milling ores, will be found in the low electrical conductivity of the water, producing currents of such low density at the cathode (amalgamating) surfaces, that fouling of the plates by the local action of some of the constituents of base ores may occur notwithstanding the polarization of the surface.

(4) *The Electro-precipitating* applications of the electric current are used to precipitate the gold by electrolysis from solutions resulting from some chemical process of treatment. They constitute the most important, being the most numerous and successful, applications of electricity in gold milling. South Africa has been the field in which this process of precipitating gold from solution has been most successfully used. It is there known as the Siemens-Halske process, and is a cyanide process, in which the gold is deposited from its cyanide solution by electrolysis.

It is similar in many respects to other forms of electrolytic applications used in plating, refining, etc. The anodes are cast-iron plates, the cathodes are of sheet lead, and when sufficiently coated with gold the latter are removed, melted and the gold cupelled. About 8,000 square feet of cathode surface is required to electrolyze 100 tons of solution in twenty-four hours. The plates are arranged to act as baffle plates to the solution which flows slowly through the series. The resulting bullion is of high grade. The process has many advantages over precipitation by zinc shavings, which it has largely replaced. It is, however, evidently best adapted to work on a large scale, and does not seem likely to replace the zinc shaving process at small plants.

(5) *The Electro-inductional* methods proposed for treating gold ores have been devised for use in working alluvial gold or free-milling ores in which the gold exists in the form of metallic grains or particles. They contemplate the use of high frequency alternating apparatus of various forms, whereby alternating currents are induced in each metallic particle, causing it to be attracted or repelled. The writer is not

informed whether any apparatus of this description has progressed beyond the laboratory stage of development. It is claimed that metallic particles can be picked up in this way as readily as magnetic particles are picked up by a magnetic separator. Should these claims be realized in practice, this method of separating gold from other materials with which it is mechanically mixed, will have a wide field of work, especially in the arid regions, where the absence of sufficient water prevents the use of the ordinary wet methods of separation.

(6). *Electro-smelting* of gold ores has been repeatedly rejected as a method too expensive for ordinary ores, and as presenting few if any advantages over ordinary smelting practice. That gold can be reduced from its ore by smelting in the electric furnace, by a smelting process alone, or by a combined smelting and electrolytic process, is generally admitted.

Another field for the application of the electric current is in electrolytic refining of base bullion, but this does not properly fall within the limits of the present article, which has aimed only to systematize by classifying the numerous ways in which it has been proposed to use the electric current in separating gold from the ores or materials with which it is associated. This field is a large and inviting one to the electrician and mining engineer alike. That it has not recorded more successful applications is perhaps largely because few electricians or inventors who have devised methods or appliances for this purpose have fully understood the conditions and requirements of milling practice. To succeed with any of these methods of treatment, accurate knowledge is required of the ores, of their chemical and physical peculiarities, and of present processes of treatment, and more especially of the exact causes of the failure of the processes in use to produce satisfactory results.

DISCUSSION.

MR. MAX LIVINGSTONE.—Dr. Chance touched upon the process of extracting gold by means of boring holes and pumping down a solvent. It sounds like a fairy tale, but that process is going to be tried on a very large scale. I am surprised that a

Philadelphia company intends to undertake it. A very eminent gentleman in Cleveland is trying to carry out this process and has men of wealth behind him. He is basing his theory on the scheme that enabled him to work the sulphur deposits of Louisiana. A French company had sunk an immense amount of money on account of their inability to reach a depth of about 450 feet by means of large tubes 4 feet in diameter. After spending two or three million dollars the matter was given up. Some years ago a gentleman from Cleveland sank a 4-inch tube to the sulphur deposit, and then in this 4-inch pipe he inserted a smaller one, forcing water down through the larger and steam under very high pressure through the smaller pipe, he melts the sulphur and brings it to the surface in liquid form. This plan is now in successful operation and has been for seven or eight months. Sulphur, which heretofore has been brought from Sicily, and commands from $18 to $24, this company claims can be delivered in New York for less than $5. Encouraged by his success, this gentleman will try this method with gold.

MR. CHRISTIE.—I heard something suggested of a similar character by a party interested in the new gold regions of British Columbia. We hear much about the wonderful economies effected on low-grade ores by the modern leaching processes, and now it is proposed to avoid the quarrying and crushing of the rock, and apply solvents to the material *in situ*, in a wholesale way. It may be a dangerous subject to disturb here, until after the third of November, but the thought arises that some day our coinage metals may cease to be precious in the present sense of the term. When we become compelled to use a rarer metal as a denominator of value, history repeating itself, a new phase of the 16 to 1 contention may arise to vex us again. Possibly by that time the scientific, invariable unit of value will be discovered, and we will all be happy and prosperous. Can Dr. Chance tell us what is the lowest grade ore now worked profitably by the use of cyanide or other solvents?

DR. CHANCE.—The amount of gold necessary for profitable working of free milling propositions depends upon the cost of mining, and upon the fineness to which the ore must be crushed to free the gold from the gangue. In the milling of what are

known as low-grade free-milling propositions, ore running less than $5 per ton can usually be worked at a profit if the recovery be 65 or 75 per cent. of assay value. The cost of mining and milling can almost invariably be brought below $2, and in some cases it is brought down to $1. In California some mines have been running profitably on ore milling less than a $1. That ore is cheaply mined, is soft and easily crushed. The Homestake in South Dakota, which is the largest operation of the kind in the United States, if I remember rightly, yielded last year something less than $5 per ton, and the cost was about $1.60. That included the cost of mining and milling. (In answer to a question he continued.) Chlorine is the most common solvent. It is more generally used than cyanide. Bromine is very similar to chlorine. Those are the three processes of established value. I would like to ask some of the gentlemen present, who are posted on electrolytic phenomena, as to what possible foundation in fact exists for this claim to the increased rate of penetration of an electrolytic solution through or into a porous substance, such as ordinary rock, or brick or clay, or any material which is permeable to the solution. The reason I ask is that the claim is made, and made persistently, and is the substance of a number of patents; but so far as I know there is no successful plant running on any of these processes. The essential feature of the claim is an increased rate of penetration due to, or caused by, the electric current.

MR. THOS. SPENCER.—It is known that the electricity facilitates the penetration of tannin in leather.

XI.

ROENTGEN PHENOMENA;—THEORY AND PRACTICE.

By ELMER G. WILLYOUNG, Active Member of the Club.

Read October 17, 1896.

THE name Roentgen Rays is one potent to charm with, and in some respects I am almost sorry that I did not disguise my subject under some other name, because now people expect when listening to a paper on X-ray* phenomena to hear something new, either as regards the theory of this peculiar action, or with reference to some novel and useful application. The work which I have been doing has been largely in the way of perfecting certain details of the apparatus, and is a matter of so purely a commercial character that I should consider it out of place to say very much about it before an audience of this kind; but when the paper was first suggested between the president and myself in the spring, very little was known generally about the subject, and it seemed to us then that it might be very interesting, purely as a matter of information, to bring before the Club at that time a few of the more fundamental and better known facts. Through some change in the arrangement of papers, however, the matter was laid over until the fall, and in the meanwhile the greater part of these facts had become public property, so that a great deal that I shall have to say will really be old.

It might be asked what special relevancy a paper of this kind has to a society of engineers. As engineering in its broadest sense must be taken as that study which deals with the transformation of energy from one form to another, and with the mechanical devices by which such transformations may be effected, and as the phenomena of X-rays and apparatus for the demonstration of such phenomena are in the line of such transformation

* The name, X-rays, was early applied to this peculiar form of radiation, or whatever it may be, on account of the algebraical significance of the letter X, the nature of the phenomena generally being an "unknown quantity."

and devices, it would seem that there is after all some justification for bringing this subject to your attention. Furthermore, it was supposed at one time that this subject contained something which might promise future value to the subject of engineering in general, and to mechanical engineering in particular, especially as regarded the possible application of X-rays to the discovery of flaws and defects in castings, and in other details of metal construction—defects which could not be obvious to the eye, but which in practice are only to be found by actual working upon the metal, and very often only after the expenditure of considerable time and labor. This matter I will take up later.

The subject naturally divides itself into two general subordinate topics:

(1) What are X-rays?

(2) What can be done with X-rays?

The first question is very difficult to answer. Indeed it is quite impossible to answer it with any degree of fullness, although it can be answered much more completely than was possible a few months ago. If we take two metallic points situated a short distance from one another and make these points the seat of a difference of E. M. F. (electro-motive force), we shall find that even at the shortest conceivable distance, a considerable E. M. F. is required to cause a spark discharge between the points. Indeed, there seems to be a certain distance (this distance depending upon the particular gas, its pressure and its temperature) at which the E. M. F. required to produce discharge is a *minimum*. If we shorten the distance the E. M. F. increases; if we increase the distance the E. M. F. again increases. If we fix these two points in the extremities of an exhausted glass tube we shall find that as the exhaustion proceeds from atmospheric pressure, the discharge will take place with greater and greater facility, until finally when we have such a vacuum as may easily be attained with any good air-pump, the discharges become luminous and the tube filled with a play of light often very beautiful to the eye. These discharges are of a peculiar character and of great variety. They are usually of the form of flickering striations which seem sometimes to advance and sometimes

to recede in the tube; by using glass of different materials we may secure fluorescent and phosphoresent effects. If, however, we carry the exhaustion to a very high state, we find the character of the discharge to greatly alter, the luminescence seems to decrease in volume and intensity and the color to change from a general tone of blue and white to a green; the E. M. F. required also begins to increase. If the exhaustion be carried to its most extreme point the E. M. F. required becomes very great, until finally, should we be able to carry the exhaustion sufficiently far, we should find that the E. M. F. required has become infinite. In other words, a perfect vacuum becomes a perfect non-conductor.

The action of the discharge phenomena in tubes in which the exhaustion has been carried to a very high degree, has been the subject of considerable study for a long time; notably by Mr. Crookes, who some years ago excited a great deal of interest in the scientific world by a series of investigations which he carried out in tubes of this class, and in which some very remarkable phenomena seemed to take place. If, for example, a highly exhausted tube in the form of a cylinder and with flat or wire electrodes sealed in at opposite ends, be connected with a proper source of high E. F. M., Mr. Crookes found that the discharge seemed to proceed only from the cathode or negative electrode; this discharge seemed to be along lines normal to the surface of the electrode; in case of a perfectly flat electrode the discharge would be a cylindrical beam normal to the plane of the electrode, and greenish in color; a concave electrode would produce a discharge focussing to a point. From the positive electrode no action could be observed; in fact the positive electrode could be located at any point of the tube without causing the direction of the discharge from the cathode to change, the discharge seeming to be dependent only upon the position and shape of the cathode. Indeed, with a sufficiently high E. M. F., the positive electrode could be omitted altogether, without materially altering the character of the discharge.

This negative discharge possesses very peculiar properties. Where it impinges upon the glass it causes a most beautiful phosphorescent effect. If a magnet be brought near the tube, the

which has perhaps never been known in connection with any single discovery. A vast number of people, including physicists, known and unknown, engineers, technical men and amateurs, immediately began to take some of these X-ray pictures, to discover new facts or applications and to announce theories of all sorts to account for the novel phenomena.

X-rays have been found to possess the following characteristics: They cannot be reflected, they cannot be refracted, they cannot be polarized; they cannot be deflected by a magnet and they cannot be deflected by electrostatic induction. They are able to penetrate through almost all solid bodies ordinarily opaque to the eye, these solid bodies seeming to be transparent to the X-rays, somewhat in the inverse ratios of their densities. Since the discovery was announced, physicists have been hard at work endeavoring to ascertain whether these phenomena were rigorously true, or whether the quantities involved were merely so small that they escaped observation. To determine this seemed absolutely necessary to the development of any theory which could properly explain the nature of the X-ray. At the present time it seems very probable that a certain small amount of reflection, refraction and polarization *could* took place. Indeed, some observers believe that they have demonstrated that they actually do take place. That it is not possible to easily demonstrate any such properties is believed by many to be merely on account of the fact that we have no media of sufficiently minute structure to produce the phenomena. For example, if we take the phenomena of polarization; in the case of electric waves having long wave length, we may easily polarize by means of a grid of wire, such grid having very considerable dimensions. In the case of light waves, which are very much shorter, we can only produce polarization by using some of nature's grids, such as Iceland spar, tourmalin, and other crystallic structures, possessing different densities along different axes. If the X-ray be of the nature of the light ray, but merely of a much shorter wave length, it is entirely conceivable that we have no natural structures which are made up with sufficient fineness to polarize such extremely short waves.

Several theories have been advanced as to the whole nature

of this action. One is the material bombardment theory, of which Mr. Tesla is, in this country, the strongest advocate. Upon this theory the action within the tube is, as explained by Mr. Tesla, a propagation of electrified particles of gas, these gas particles being shot with such immense velocity as to be thrown entirely outside the tube and to pursue their path in the external atmosphere. The increase of vacuum which takes place in most tubes after they have been used for some time, is held to be a confirmation of this view. The majority of physicists, however, have been inclined to believe from the start that the action, *outside* of the tube at least, is a wave action either longitudinal or transverse, with the preponderance of opinion inclined to the transverse, but the waves being of exceedingly short length.* But to reconcile this view with the absence of refraction and other phenomena peculiar to light waves, was for a considerable time very much of a puzzle, until quite recently it was found that there was an old theory announced several years ago by Helmholtz, which would account for this absence of polarization, refraction and reflection, assuming the waves to be of exceedingly short wave length. To put the theory in a very rough way, let us consider the structure of a gaseous volume. This, as I have before said, may be considered as made up of a large number of material particles floating in a medium of ether. Light vibrations emanating from such a gaseous volume, are considered to be due to a vibration taking place in these atomic particles. This vibration might be either a physical vibration of the particle, or a more rapid vibration of an electric charge of which the particle might be possessed. In such a structure it is evident that there are considerable spaces of ether existing between and around each atomic particle. If we consider light waves impinging upon such a gas, these solid particles will impede the waves so long as the latter possess a sufficiently great wave length and amplitude. But if the frequency of vibration should increase and the amplitude diminish, we can see that after a time the waves will be able to pass directly through

* Since this paper was read, several European physicists have announced measurements indicating a wave length for X-ray vibration of about one fifteenth that of ultra-violet light.

these ether interstices and hence will not be impeded, that is we have no refraction. According to the view which has been here outlined, the X-rays are merely transverse vibrations in the ether, just as our light waves, but possessed of exceedingly short wave lengths.

Another fact that seems to indicate very strongly that these rays are of the nature of light rays, is the discovery which has recently been made that certain salts, such as zinc sulphide, calcium sulphide and the uranium salts, have the peculiar property, after they have been subjected to the action of light, of emitting rays very similar to these X-rays. If such a salt after being exposed to light, be taken into a dark room and be placed over a photographic plate, with some solid object between, after a certain time, an image of this object will be found upon the dry plate. It does not seem at all probable that anything of this kind could be due to material propagation; the action reminds us of radiation phenomena. These rays of "dark light" as they have been called, may be reflected and refracted. We see therefore that they possess some properties similar to those of light waves and some properties similar to X-rays, making therefore a connecting link between the two.

Still another fact which seems to ally the X-rays to the action of light, is the fact that they will discharge any body electrified statically, whether the electrification be negative or positive. If we surround a charged body with a di-electric and allow X-rays to fall upon the same, the di-electric is temporarily converted into a conductor. If ultra-violet *light* be allowed to fall upon a *negatively* charged body the body also loses its charge.

Careful study of the action shows that, within the tube, the X-rays *begin* at the surface of impact of the cathode beam upon any obstructing body. In the pear-shaped Crookes tubes, so much used in the early X-ray experiments, the fluorescent surface of the glass was the origin. In the later tubes in which the cathode beam impinges upon a platinum reflector placed in its path, the surface of the platinum becomes the source. *Before* reaching the obstructing surface the rays are *cathode* rays, while *afterward* they are X-rays. Some have thought the X-rays due to *mechanical* impact and *mechanical* vibration pure and sim-

ple, the bombarding atoms producing a very high frequency shiver in the molecular constituents of the surface upon which they impinge. Or we might explain the action electrically by supposing an electrical oscillation to be set up upon the atoms of the bombarded surface,* this oscillation being due to the inductive influence of the rapidly advancing and swiftly rebounding changes of negative electricity which exist upon the constituents of the discharge beam. It seems to me that this latter is a very reasonable explanation, as it would give the wave action the very high frequency necessary to account for the absence of refraction, polarization, etc., as I have before explained, the waves of light proper being supposed due to the electrical strains produced in the ether by the oscillatory motion of the charges *not* upon the atoms themselves, but by virtue of their change of position *with* the mechanical change in form of the atom itself, the latter being supposed to be in a condition of *mechanical* vibration.

Useful results obtained to date have been largely in the line of medicine and surgery. In these fields they have more than justified expectation. When you see upon the screen the slides which will be shown I think you will agree with me. In determining trouble in the bony structure, such as injuries or abnormal growths, X-rays are of great value; so also in locating bullets, shot, or foreign substances of any kind within the body. Already there have been successfully performed a sufficient number of surgical operations which could *not* have been performed without the aid of this new agent, to warrant designating this discovery as one of the most important to the welfare of the human race ever made.

I have referred to the fact that some hopes were indulged in as to a possible future value of the X-rays in engineering work. These hopes have proved idle, and I see no way in which it seems likely that engineering may at all benefit. The difficulty is a very obvious one: if we imagine a blow hole in a casting of any size and imagine the actual thickness of solid metal along any

* Many phenomena, both in physics and in the study of chemical affinities, indicate that all atoms are naturally possessed of a charge of electricity, this charge being a permanent one which cannot be removed.

line passing through this hole, we readily see that this thickness is likely to be nearly as great as the thickness measured along any other practically parallel line. In an X-ray photograph therefore we should get no contrast to speak of and the defect would remain undiscovered. Of course, in very small castings we might succeed a little better, but small castings are not so important.

X-rays may be used to distinguish between genuine and artificial diamonds, imitation stones being very opaque and genuine gems quite transparent. Certain porcelains also may be discriminated. Much has also been written at one time and another regarding a supposed action of X-rays upon bacteria; concerning this it may

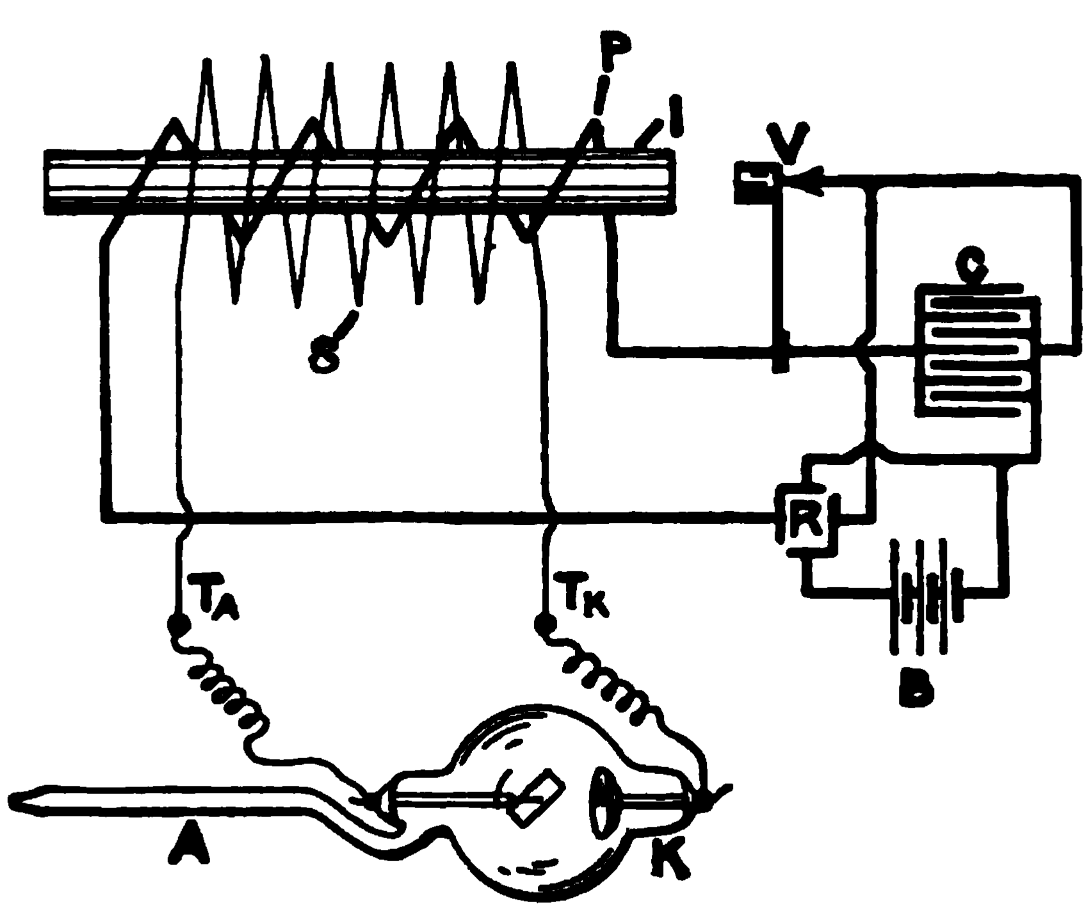


FIG. 1.—DIAGRAM OF INDUCTION COIL.

be said that not the slightest shred of reliable experimental testimony has thus far been advanced to show any such action.

A few words as to the apparatus. This consists essentially of a proper tube and a source of high E. M. F. This last is generally secured by some form of induction coil. The induction coil is merely a high potential transformer with a thick wire coil, carrying a low potential current as primary and a secondary of many turns of very fine wire by which the primary current is transformed into one of small amperage but extremely high E. M. F. Fig. I shows such a coil. To operate it an intermittent current is sent through the primary, inducing an instantaneous high E. M. F.

in the secondary at make and a similar E. M. E., but in the opposite direction, at break. By using a condenser, *C*, the induced E. M. F. at break is caused to be so very much higher than that at make* that we have practically a series of uni-directional discharges. The requisite intermittence of discharge may be obtained either by some form of vibrating magnetic break, operated by the iron core of the primary itself, much as is the vibrating hammer of the ordinary electric bell, or a device may be operated by a small motor. Some advocate the use of alternating currents, thus dispensing with a break altogether. My own experience is entirely

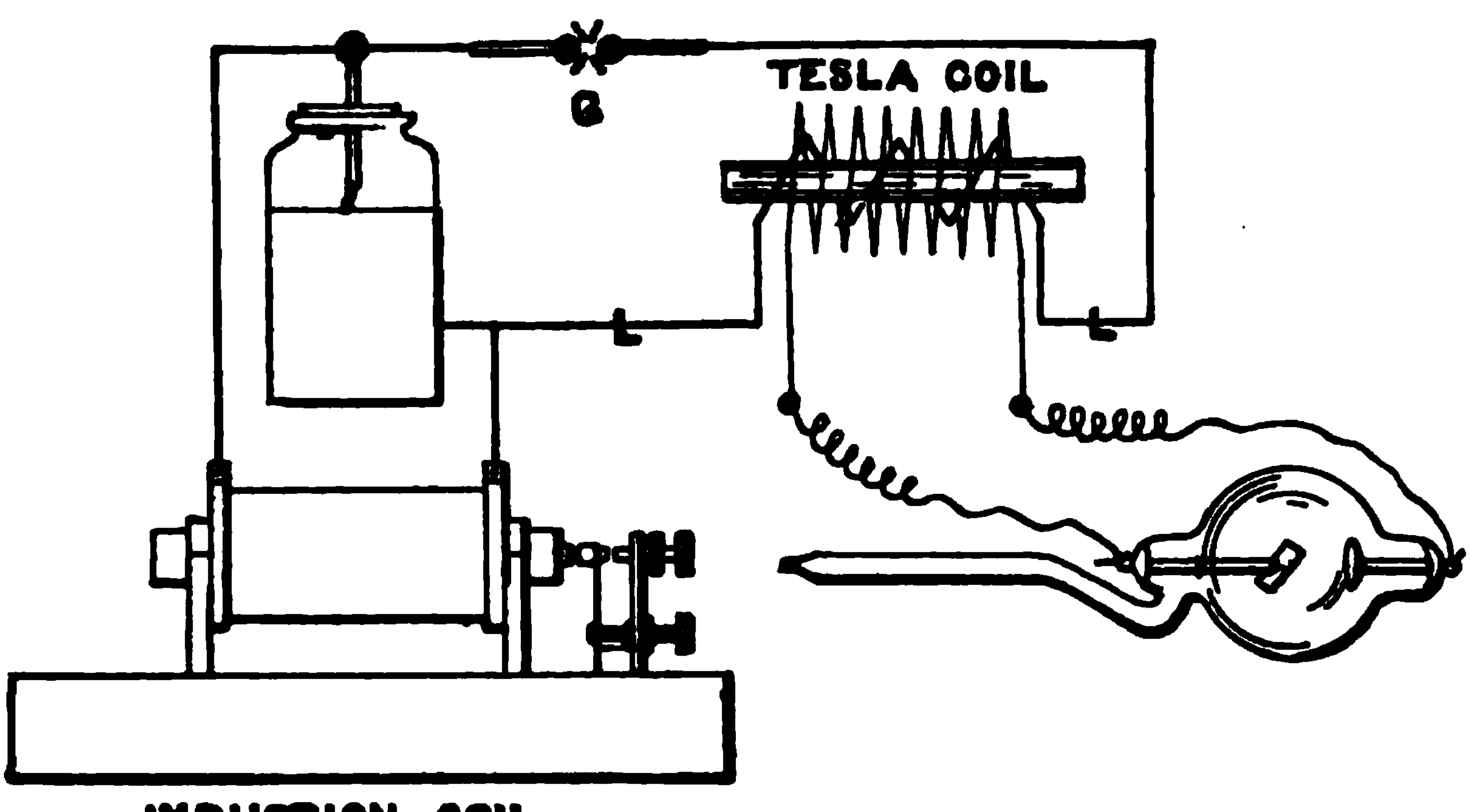


FIG. 2.—DIAGRAM OF TESLA COIL.

opposed to this. An alternating current is usually an approximation to a sine curve and passes *gradually* through the zero value of current. It is impossible with it to get the *abruptness* produced by the intermittent current, and this abruptness is imperative to the production of high E. M. F.s in the secondary. If we use enough current to make up for this lack of abruptness, we should require to use so much *energy* in the primary as to produce undue heating and seriously endanger the safety of the coil.

Often what is known as a Tesla combination is used. This (Fig. 2) is made up merely of an ordinary induction coil (but

* See Fleming's "The Alternate Current Transformer," for a complete discussion of the theory of the induction coil.

with condenser omitted) and a *second* induction coil, the secondary of the first coil being joined in series with the primary of the second coil *and an air gap.* A Leyden jar has its inside connected to one secondary terminal of the first coil and its outside to the other. An alternating current is used in the primary of the first coil. As the Leyden jar *charges*, it immediately discharges disruptively across the air gap, producing an oscillating current in the primary of the second coil and an induced current of tremendously high frequency and E. M. F. in the secondary of the same coil. These E. M. F.s are so high as to require the most perfect insulation in the second coil—usually the coil is immersed as a whole in a bath of oil. The form of discharge given off from the secondary of a Tesla coil, unlike that of the induction coil, is alternating. This requires, to get good definition in the photographic result, either a *diaphragm* or else a form of tube in which *both* the electrodes will focus their " cathode " rays upon practically the same point. The " double focus " tube of Prof. Elihu Thompson answers this purpose admirably.

Of the two types of apparatus I emphatically favor the induction coil rather than the Tesla form. The former gives fully as good results if not better, and is much simpler in construction. The Tesla coil has an objection, also, very grave from the medical and surgical standpoint, and exceedingly annoying from *any*, viz., the violent *smashing* noise produced by disruptive Leyden jar discharge. With the induction coil there is practically *no* noise whatever when the tube is in action. Of course, when an alternating current is at hand and recourse must otherwise be had to primary batteries or to storage batteries requiring to be sent some distance for charging, the above disadvantages just referred to may be outweighed.

Induction coils have been usually operated from primary or storage batteries, or some *low voltage* source. With the orthodox form of vibrating break this has been imperative owing to the rapidly destructive action of primary spark at break upon the contact points when high E. M. F.s are used. The writer and his associate, Mr. H. Lyman Sayen, have been engaged for some time in seeking a solution of the problem of running coils upon ordinary commercial circuits of 110 volts or over. It is believed that this has been attained in a thoroughly satisfactory manner.

Fig. 3 represents the apparatus which we have devised for this purpose. It consists essentially of a wheel of brass, having its periphery periodically interrupted by stretches of slate flushed into the wheel. The wheel is attached to the spindle of a small $\frac{1}{12}$ H. P. motor, passing vertically up through a copper can filled with distilled water, and the break wheel runs in it. In the base of the apparatus is an adjustable resistance by which the motor speed may be varied at will. In operation the apparatus

FIG. 3.—ROTARY BREAK.

is practically noiseless—the sparking being so slight that after an hour's running the water is only warm.

I have a number of slides which will now be shown upon the screen; they are all of medical or surgical subjects, and were made by Dr. A. W. Goodspeed, of the University of Pennsylvania, who has kindly loaned them to me for this evening's use. Dr. Goodspeed was one of the first men in this country to apply himself to improvement in the *technique* of X-rays, and has done work which in my opinion has not been surpassed anywhere.

(At the close of the paper a large number of interesting slides were shown by Dr. Goodspeed.)

DISCUSSION.

Prof. Edwin J. Houston.—In the opinion of Prof. J. J. Thomson, we have as yet no crucial experiment which unmistakably shows that the X-rays are transverse vibrations in the ether, or waves of normal vibration, or, indeed, vibrations at all. If they are transverse vibrations, they must, be of an entirely different order from those of ordinary light. The phenomena of the X-rays can be divided into two distinct classes, namely: (1) The phenomena as they exist inside the tube. (2) The phenomena as they exist outside the tube. Inside the tube we have the cathode rays. These would appear unquestionably to consist of streams of negatively electrified molecules moving with high velocities. This would appear from the deflection of the cathode rays by magnetic flux, and by the phosphorescence they produce on impact against the glass, or other suitable material.

Outside the tube, we have two classes of rays: the Lenard rays, and the X-rays. The Lenard rays, like the cathode rays, appear to consist of streams of electrified molecules; but whether the Lenard rays are produced by streams of the molecules of the residual gas within the tube, or of convection streams of gases outside the tube, is an open question. Tesla believes that the X-rays consist of convection streams of the residual molecules from within the tube, actually propagated through the glass. I think this very questionable, even in the case of the Lenard rays. If the X-rays are caused by transverse ether vibrations, they must be of an entirely different order from those of ordinary light. Of course, Helmholtz's theory, as to the effect of the frequeney of vibration on the refractive index, would satisfactorily explain why the absence of refraction might not necessarily establish the impossibility of transverse vibration. Then again, we might not be able to produce the phenomena of polarization of the X-rays, from our want of a sufficiently fine grained polarizer. On the whole, I think we can safely say that the phenomena are still correctly represented by the sign x, taken as typical of an unknown quantity.

ADDENDUM.

THE FOLLOWING ILLUSTRATIONS ARE THOSE REFERRED TO ON PAGE 109 OF THE JULY NUMBER OF THE PROCEEDINGS, IN THE PAPER ON "*The Welsbach Light and Other Incandescent Gas Lights*," BY GEORGE S. BARROWS.

Directions to Binder: **Reject this sheet and bind the following four inserts between pages 108 and 109.**

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 3, November, 1896.]

Fig. 1.—A New Welsbach Mantle which has just been burned out.

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No, 3. November, 1896.]

Fig. 2.—A Welsbach Mantle which has been burning for 168 hours.

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 3, November, 1896.]

Fig. 3.—A Welsbach Mantle which has been burning for 100 hours.

Fig. 4.—Shrinkage of the Mantle after burning.

NOTES AND COMMUNICATIONS.

THE WORK OF THE METROPOLITAN WATER BOARD OF MASSACHUSETTS.

At the meeting of October 17th, Mr. Dexter Brackett of the Metropolitan Water Board of Boston, was invited to make some remarks and spoke as follows:

"A few years ago the question of the supply of water for many of the cities and towns adjoining Boston became to them a very serious question, and as the city of Boston itself was also approaching the time when it would need an additional supply, it was suggested that the matter be placed in the hands of the State, so that a supply could be obtained which should supply all of these municipalities, rather than have each one looking after its own.

"Boston differs somewhat from other large cities, in that there is a very large suburban population. Nearly one half of the population residing within twelve miles of the State House is beyond the limits of the city of Boston, and in the matter of sewerage, that question had already been settled by building, under the direction of the State, works for the sewerage of most of those cities and towns, and it was therefore but natural that the same idea should suggest itself respecting the water supply. The question was investigated under the direction of the State Board of Health, and about two years ago by the Legislature, and in the winter of 1894–95 an Act was passed, authorizing the construction of works for the supply of all the cities and towns within twelve miles of Boston, appropriating $26,000,000 for that purpose. The original appropriation was $19,000,000 for building new works, but the Bill as passed provided for the purchase of the works now supplying the city of Boston, and for joining them with the works now being built.

"About a year ago the work of preparing plans was commenced under the direction of a Board, and it is to be prosecuted under the direction of a Board of three, appointed by the Governor of the State, and confirmed by the Governor's Council. It may possibly interest you to know that the work of the Board is carried on entirely free from any political influence. All of the engineers, of which we now have about 150, are employed by the chief engineer, and, in no instance whatever, has outside pressure been permitted to influence appointments. The same is true, also, of all the subordinates. Of course, the work is largely done by contract. The theory upon which the work is done is that the Board is a business board. The work to be done comprises the construction of a storage reservoir on the Nashua river, about 35 miles from Boston. The storage reservoir will be the largest artificial one in the world. It will contain about 63,000,000,000 gallons, and will be about 8½ miles long and 2 miles in width at points. The average depth is about 46 feet, but a great portion of the basin is from 80 to 100 feet in depth. From this reservoir the water is to be conducted, through a masonry aqueduct, about 9 miles, 2 miles of this in a tunnel, and then through 3 miles of open channel to a reservoir which is now being completed by the Metropolitan Board. From that point, the water will be conducted to the city for the present through the aqueducts of the Boston works. In the course of ten or twelve years another aqueduct is to be built. The aqueduct under construction has a capacity of 300,000,000 gallons per day; it is of the horse-shoe shape. One of the

novel features is that the arch, 12 feet in diameter, is entirely of Portland cement concrete.

"In connection with the distribution there is a large amount of work to be done. Excepting its magnitude, there is nothing peculiar or novel about it. We have some large pumping stations and storage reservoirs."

Mr. John C. Trautwine, Jr., added: "The work of the Metropolitan Board is one of peculiar interest to me, involving, as it does, the idea of a State supply, which I had broached in my report for 1895. Pennsylvania is peculiarly fitted for something of the kind. I believe that the ideal supply for us is one under the charge of the State, or under an interstate commission, which should have absolute control of the waste or timbered water-bearing lands, and protect them from pollution and from forest devastation, and which should construct aqueducts and distribute water to the different towns, as the city now distributes water to its different wards. Massachusetts seems to lead the way in matters of education and of politics, and Pennsylvania should gladly accept this object-lesson from the pioneer state."

BOOK REVIEWS.

SCHAEDEN AN DAMPFKESSELN, Heft II; SCHAEDEN AN STABILKESSELN. Herausgegeben vom Oesterreichischen Ingenieur und Architekten Vereine. Wien, 1896. Price, 5 Marks.

This publication presents in a concise, convenient form the injuries which stationary boilers are subject to and deals with the causes, conseqences, prevention and repair of the same. This work is unique in its conception and execution. Some years ago the Austrian Association of Engineers and Architects undertook the task of presenting in a condensed and easily accessible form a description and treatment of such injuries to boilers as most frequently occur. For this purpose a special committee was appointed consisting of practical engineers, professors, and members of boiler inspection and insurance companies. The committee received the cordial aid of manufacturers of boilers and others, particularly in obtaining the excellent phototypes of specimens which enrich the publication and illustrate damages sustained by the various parts of boilers. The plan decided upon was to divide the work into three parts, the first of which was to treat of locomotive and portable boilers, the second of stationary boilers, and the third of marine boilers. The first part was published in 1891 and was so favorably received, that the committee was stimulated to increased efforts in producing the second part, to which it added the excellent illustrations already referred to. Throughout the work, both in classification and minute details, the patience and painstaking accuracy characteristic of the Austrians are apparent.

The inquiries are taken up under the several headings, Deformation of structure, Corrosion and wasting away, Rupture, Fractures and Defective material.

The double pages are divided into five columns headed respectively: (1) Appearance of Injury, which is illustrated by drawings throughout. (2) Location. (3) Cause. (4) Consequence. (5) Prevention and Repair, which latter column contains numerous explanatory cuts. Each kind of injury illustrated is numbered and this

number is carried through the five columns. Some of the causes given indicate theories, which will probably not receive the approval of many American engineers. Thus in several instances the cause of burning the sheets is ascribed to the interposition of steam between the water and the plate. In order to make this reason valid the steam would have to be highly superheated in close contact with water, which is manifestly not tenable. Some of the forms of construction which are criticised and evidently in use more or less in Austria, are prohibited in most American cities by the boiler inspection laws. Thus the cutting out of the sheet on which the dome is mounted to the full diameter, is prohibited in Philadelphia. Differences in the tendencies of practice can also be noticed, thus where the authors recommend the thickening of tube sheets and avoidance of stay tubes, the latest practice in this country seems to tend to the use of light tube sheets to provide for expansion and contraction.

Following the text of the book are plates showing injured parts as photographed from the actual specimens covering cracks, bulges, pitting, etc. Finally a series of plates are presented giving sketches showing the usual construction of various boilers and their setting. A number of forms are here illustrated which are rarely or never seen in this country.

The publication appears in pamphlet form and should constitute a valuable and interesting book of reference. It can be obtained by addressing the Secretary of the Austrian Association of Engineers and Architects, Vienna, 1 Eschenbachgasse No. 9. The third part is to be published next year. A. F.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS; being the Proceedings of the Society at its Eleventh Annual Meeting, held at Galesburg, Ill., January 29, 30 and 31, 1896. Price 50 cents.

This valuable number of the Society's report is made up of a large number of short papers, discussions, committee reports, etc., bearing largely upon questions of water supply and sanitation.

Mr. C. C. Stowell describes and illustrates the use of the air-lift pump at the water works of Rockford, Ill.

Mr. Chas. E. Wells, of Boston, briefly describes, in a paper without illustrations, the great Nashua reservoir and aqueduct of the Metropolitan water-supply for Boston and its vicinity. The maximum height of the reservoir dam above the rock at its down-stream edge is 158 feet; the area of the lake is 4,194 acres and its capacity is about 63,068 million gallons. The cost of the dam is estimated at $1,723,010, while that of removing the soil from the bottom of the reservoir is over $2,900,000. The aqueduct, twelve miles long, and capable of flowing 300 million gallons per day, is estimated to cost $2,265,000.

Mr. Daniel W. Mead, of Rockford, Ill., contributes an interesting illustrated paper on the Hydraulic Ram, tracing briefly the history of the development of that machine and illustrating various modern forms, including the "Rifle" ram, designed to raise water from a pure source by means of water from an impure source, and two designs by the author himself.

Mr. W. D. Pence, of Champaign, Ill., describes a test of the discharge of an artesian well by means of a 2-inch Empire and a 4-inch Crown meter. The operation of both meters, and especially that of the smaller one, was much impeded by the sand brought up by the water. The sand scratched the meters considerably.

Other important papers are "Sanitary Engineering and State Board of Health," by J. A. Harman; "Sewage Irrigation for Profit," by Walter C. Parmley, and "A Topographical Survey of the State of Illinois," by John W. Alvord.

The volume closes with committee reports on Land Drainage, Tests for Paving Brick and Sewer Pipe, Cost of Public Work, Instruments, etc., General Engineering, Legislation and Water Supply. J. C. T.

COMPUTATION RULES AND LOGARITHMS, WITH TABLES OF OTHER USEFUL FUNCTIONS, by SILAS W. HOLMAN. New York: Macmillan & Co., 1896. Pp. xlv, 73.

The first portion of the work is devoted to computation rules. A general idea of these can be obtained from the following quotation: "In direct multiplication or division, retain in every factor, product and quotient throughout the entire process, and in final results, for an accuracy of about one per cent., or worse, four places of significant figures. One-tenth per cent., or worse, five places of significant figures," and in using logarithms use four-place tables for about one per cent. accuracy, etc. A series of problems are worked out in detail, showing the application of the rules laid down. These are clear and to the point. The second portion of the rules relates to logarithms, giving the usual rules for using them and examples. The details of the method of using the tables are useful for beginners only, as one who is constantly using such tables finds that in most of the work to be done these can be much simplified.

Following the rules relating to logarithms are a few pages covering the definitions and explanations underlying the computation rules.

The tables occupying the last seventy-three pages are four-place logarithms, four-place anti-logarithms and four-place co-logarithms, the last two of which might better have been omitted; tables of five-place logarithms; tables of squares and sqare roots, reciprocals, slide wire ratios, tables of trigonometric functions both natural and logarithmic, and tables of constants and their logarithms.

The tables are conveniently arranged for use, thus page 29 gives the five-place logarithms of numbers from 9.500 to 9.999. It has at the upper and lower right hand corners (it is the right-hand page) printed in bold-faced type $5 \overset{Pl.}{9.} Logs$, showing just what the page contains. On the right of the table are printed the figures $\frac{.95}{.99}$, meaning that the logarithms to be found on the two pages open are between .95— and .99—, thus making it easy to locate the number corresponding to any logarithm. In the body of the tables large spaces are left at 9.600, 9.700, etc., and smaller ones at 9.550, 9.650, etc.

The book is convenient and accurate and in any work requiring more than three-place logarithms will be found useful. The rules for computation would, if generally understood and practiced, reduce much of the present tedious calculations to comparatively easy ones and at the same time give one a clearer idea of the amount of reliance to be placed on the results. H. W. S.

ABSTRACT OF MINUTES OF THE CLUB.

REGULAR MEETING, September 19, 1896.—President A. Falkenau in the chair. Forty-five members and visitors present.

The Secretary announced the deaths of two Active Members, Messrs. Thomas Roney Williamson, on September 12, 1896, and Louis Prevost Evans, on August 19, 1896.

The paper of the evening, on "The Water Supply of Philadelphia—Considered with Reference to the Minimum Flow of the Schuylkill River," was presented by Mr. Edwin F. Smith, and was illustrated by blue prints and lantern slides.

BUSINESS MEETING, October 3, 1896.—President A. Falkenau in the chair. Sixty-five members and visitors present.

The tellers reported that at the election of this date Messrs. George W. Pfeiffer, George Neville Leiper, Louis Raymond Shellenberger, Alan Wood, 3d, and Franklin Davenport Howell, Jr., had been elected to Active Membership, and Mr. George M. S. Armstrong to Associate Membership.

Mr. Richard L. Humphrey presented the paper of the evening on "The Cement Laboratory of the City of Philadelphia," with special reference to the equipment and methods of operation of the laboratories in question.

REGULAR MEETING, October 17, 1896.—President A. Falkenau in the chair. Eighty-two members and visitors present.

Mr. Elmer G. Willyoung presented a communication on "Roentgen Phenomena; Theory and Practice." At the close of his remarks, Mr. Willyoung invited Dr. A. W. Goodspeed, from the University of Pennsylvania, to describe a series of lantern slides from shadowgraphs which the latter had made by means of the Roentgen rays. These were all of different parts of the human body, taken generally for the purpose of discovering injuries to the bones, or foreign bodies imbedded in the flesh.

Dr. H. M. Chance then presented a paper on "Electricity in Gold Milling."

The Secretary read an invitation from the Technical Club of Chicago, to members of this Club, to use the Club rooms in Chicago whenever any of them may be visiting that city during 1896. The thanks of the meeting were tendered to the Technical Club for this courtesy.

At the invitation of the President, Mr. Dexter Brackett, visitor, of the Metropolitan Water Board of Massachusetts, gave a brief description of the work that has been done by the State of Massachusetts for supplying Boston and neighboring towns with pure water. (See under *Notes and Communications.*)

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, September 19, 1896.—Present: President A. Falkenau; Vice-Presidents John L. Gill, Jr., and Carl Hering; Directors W. C. Furber, Henry Leffmann, Max Livingston, L. Y. Schermerhorn and the Secretary.

The Treasurer's Reports for June, July and August, showed:

Balance from May	1,218 26	
Received during June	197 50	
" " July	153 85	
" " August	126 35	
		$1,695 96
Expended during June	$393 38	
" " July	563 40	
" " August	280 69	
		$1,237 47
Balance August 31, 1896		$458 49

The resignation of Mr. M. H. Harrington from Active Membership, was presented and accepted.

The House Committee presented a report of fixed charges and ordinary expenditures for the fiscal year 1896, and, upon motion, an appropriation of $2,163.41 was made to that Committee for the year's total, in accordance with this report.

The Membership Committee reported that a new form of application was being prepared by the Committee, in accordance with the requirements of the new By-Laws.

REGULAR MEETING, October 17, 1896.—Present: President A. Falkenau; Vice-Presidents John L. Gill, Jr., and Carl Hering; Directors, W. C. Furber, Henry Leffmann, Edgar Marburg, L. Y. Schermerhorn, Jos. T. Richards, Max Livingston, and the Secretary.

The President called attention to the uncertainty as to the standing of recently graduated college students for admission to the Club, and upon motion the Membership Committee was instructed to formulate regulations as to the admission of members to the different classes in the Club.

The Treasurer's report showed:

Balance from August	$458 49	
Received during September	201 70	
		$660 19
Expended during September		195 85
Balance September 30, 1896		$464 34

The Membership Committee reported a new form of application for membership, similar to that of the American Society of Civil Engineers, and recommended that a separate slip be issued with this, to give applicants other information regarding membership. This form was accepted after a slight amendment.

CONTRIBUTIONS TO THE LIBRARY.

FROM JUNE 15, TO OCTOBER 15, 1896.

FROM ALABAMA INDUSTRIAL AND SCIENTIFIC SOCIETY.

Proceedings, Volume VI, Part I, 1896.

FROM AMERICAN INSTITUTE OF MINING ENGINEERS.

Transactions, Volume XXV, February to October, 1895.

FROM AMERICAN PHILOSOPHICAL SOCIETY.

Proceedings, January, 1896.

FROM ASSOCIATION TECHNIQUE MARITIME, PARIS.

Bulletins, Sessions 1890, 1891, 1892, 1893, 1895.

FROM CITY ENGINEER OF TORONTO.

Annual Report, 1895.

FROM COMMISSIONER OF EDUCATION, WASHINGTON, D. C.

Report, 1893–94, Volumes I and II.

FROM ENGINEERING ASSOCIATION OF THE SOUTH.

Proceedings, Volume VII, April, 1896.

FROM FORD & BACON.

Recent Engineering Work.

FROM ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.

Eleventh Annual Report, 1896.

FROM INSTITUTION OF CIVIL ENGINEERS, LONDON.

Abstracts of Papers in Foreign Transactions and Periodicals.
Connecting-Rod; Hill.
Crank Angle for Greatest Piston Velocity; Unwin.
Dredging Ports on Lake Titicaca; Clark.
English and American Locomotives in Japan; Trevithick.
Extraction of Silver, Copper and Tin; Clewes, Courtney, McKillop and Ellis.
Gas Engines; Clerk.
Grain Appliances at Millwall Docks; Duckham.
Iron Tunnels; Leitch.
Littoral Drift; Wheeler.
Machinery Bearings; Dewrance.
Magnetic Testing of Iron and Steel; Ewing.
Magnetic Data of Iron and Steel; Parshall.
Manufacture of Aluminum; Hunt.
Montreal Electric Street Railways; Cunningham.

North Caisson, Madras Harbor; Thompson.
Physical Experiment in Relation to Engineering; Kennedy.
Repairs to a Submerged Main; Macdougal.
Sanitary Works of Buenos Ayres; Parsons.
Sewage and Refuse Disposal; Butterworth.
Tampico Harbor Works; Corthell.
Trials of an Express Locomotive; Adams and Pettigrew.

FROM INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

Transactions, Volume XXIII, 1894; Volume XXIV, 1895.

FROM HENRY LEFFMANN.

Dietetic and Hygienic Gazette.

FROM LIVERPOOL ENGINEERING SOCIETY.

Transactions, Volume XVII, 1896.

FROM MASTER CAR BUILDERS' ASSOCIATION.

Proceedings, Volume XXX, 1896.

FROM NOVA SCOTIAN INSTITUTE OF SCIENCE.

Proceedings and Transactions, Session of 1894–1895.

FROM OESTERREICHISCHEN INGENIEUR- UND ARCHITEKTEN-VEREINE.

Schäden an Dampfkesseln; Heft II: Schäden an Stabilkesseln.

FROM PATENT OFFICE, LONDON.

Patents for Inventions, Abridgments of Specifications:
Acids and Salts, Organic, and other Carbon Compounds.
Advertising and Displaying.
Agricultural Appliances, Farmyard and Like.
Agricultural Appliances for the Treatment of Land and Crops.
Air and Gas Engines.
Bells, Gongs, Foghorns, Sirens and Whistles.
Bleaching, Dyeing and Washing Textile Materials, Yarns, Fabrics and the Like.
Casks and Barrels.
Chimneys and Flues.
Coin-freed Apparatus and the Like.
Cutlery.
Distilling, Concentrating, Evaporating and Condensing Liquids.
Dynamo-Electric Generators and Motors.
Electric Lamps and Furnaces.
Electrolysis.
Fencing, Trellis and Wire Netting.
Fire, Extinction and Prevention of.
Food Preparation and Food Preserving.
Galvanic Batteries.
Gas Distribution.

Glass.
Governors, Speed Regulating for Engines and Machinery.
Harness and Saddlery.
Hinges, Hinge Joints, and Door and Gate Furniture and Accessories.
Horse Shoes.
Injectors and Ejectors.
Leather.
Locomotives and Motor Vehicles for Road and Rail.
Milking, Churning and Cheesemaking.
Mixing and Agitating Machines and Appliances.
Oils, Fats, Lubricants, Candles and Soaps.
Ordnance and Machine Guns.
Paper, Paste-Board and Papier-Mache.
Photography.
Pipes, Tubes and Hose.
Printing, Letter-press and Lithographic.
Railway and Tramway Vehicles.
Railway Signals and Communicating Apparatus.
Ropes and Cords.
Ships, Boats and Rafts, Division II.
Ships, Boats and Rafts, Division III.
Spinning.
Steam Engines.
Stone, Marble and the Like, Cutting and Working.
Toilet and Hairdressing Articles and Perfumery.
Velocipedes.
Wearing and Woven Fabrics.
Weighing Apparatus.
Wheels for Vehicles.
Writing Instruments and Stationery and Writing Accessories.

FROM ROCHESTER ACADEMY OF SCIENCE.

Proceedings, Volume III, Brochure 1.

FROM SECRETARY OF INTERNAL AFFAIRS, HARRISBURG.

Annual Report, 1895.

FROM JOHN C. TRAUTWINE, JR.

Experiments upon the Contraction of the Liquid Vein issuing from an Orifice and upon the Distribution of the Velocities within it.

FROM U. S. COAST AND GEODETIC SURVEY.

Report, 1894, Part II.

FROM U. S. GEOLOGICAL SURVEY.

Bear River Formation and its Characteristic Fauna; White.
Cambrian Rocks of Pennsylvania; Walcott.
Constitution of the Silicates; Clarke.

Contributions to the Cretaceous Paleontology of the Pacific Coast: The Fauna of the Knoxville Beds; Stanton.
Dictionary of Geographic Positions; Gannett.
Disseminated Lead Ores of Southeastern Missouri; Winslow.
Earthquakes in California in 1894; Perrinn.
Fifteenth Annual Report, 1893–94.
Mineralogical Lexicon of Franklin, Hampshire and Hampden Counties, Massachusetts; Emerson.
Mineral Products of the United States, Calendar Years 1886–1895.
Report of Progress of the Division of Hydrography for the Calendar Years 1893 and 1894; Newell.
Revision of the American Fossil Cockroaches, with Descriptions of New Forms; Scudder.
Sixteenth Annual Report, 1894–95.

FROM UNIVERSITY OF WISCONSIN.

A Complete Test of Modern American Transformers of Moderate Capacities.
Problem of Economical Heat, Light and Power Supply for Building Blocks, School Houses, Dwellings, etc.

FROM WAGNER FREE INSTITUTE OF SCIENCE.

Transactions, Volume IV, January, 1896.

FROM WAR DEPARTMENT, WASHINGTON, D. C.

On Tests of Construction Materials.
Resolutions of the Conventions held at Munich, Dresden, Berlin and Vienna.

FROM F. H. WILSON.

Queer Doings in the Navy.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.
INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XIII.] JANUARY, 1897. [No. 4.

XII.

THE QUEEN LANE DIVISION OF THE WATER WORKS OF PHILADELPHIA.

PART IV*.—THE DISTRIBUTING SYSTEM.

By ALLEN J. FULLER, Active Member of the Club.

Read November 7, 1896.

IN 1797, the Councils of Philadelphia were petitioned to supply the city with water, and in the following year Mr. Benjamin H. Latrobe presented a report on several proposed schemes, including that of an aqueduct from Spring Mill, or from the Wissahickon Creek, of power works, and of a system of impounding reservoirs. These measures provoked considerable discussion, of which, unfortunately, there is but little record.

In 1799, the "Centre Square and Schuylkill Works" plan was adopted, and it was one of the marvelous features of those early days that this most advanced, and yet most difficult and almost impracticable scheme was selected, instead of the much better comprehended gravity and impounding reservoir projects. The construction of the Centre Square and Schuylkill Works was a typical American achievement, daring in conception, and accom-

* For Parts I, II and III, see pages 35, 41, and 47 respectively.

of greatest consumption is 53,000,000 gallons, 191 gallons per capita per diem, and inasmuch as the consumption of water during the day is one-third in excess of that during the night, the maximum consumption during the day will, therefore, be at the rate of 71,000,000 gallons per twenty-four hours.

The Queen Lane pumping station and reservoir were designed to supply the above-described district. The station, Fig. 1, contains four pumps, having a total daily capacity of 80,000,000 gallons. The "intake" is located on the Schuylkill River. The Queen Lane intake, Fig. 2, is built of masonry, and is rectangular in form, with a wall 46 feet long by 24 feet wide and 21 feet deep, divided into two equal sections, of 20 x 24 feet, by a wall, the top of which is 8.66 feet below that of the main structure.

The front, or river wall, is pierced with three openings or sluice ways for each section. Each opening is 2.96 feet wide and 4 feet high, and controlled by vertical sliding gates at the outer end.

Masonry piers project 5 feet from the face of the wall at the center and at each end, thus leaving two spaces 18 feet wide and 19.5 feet high, in which are placed the heavy iron screens.

The two end piers are further extended a distance of 7 feet to form a breakwater, or means of protection for the screens. A heavy dry-laid wall also extends up and down stream from the piers for a distance of 60 feet.

The masonry fronting the river is of rock-faced Pennsylvania granite, laid in 19½ inch courses. The rough work is of Conshohocken stone; the floor in the bottom of the well, and between the screens and the river wall, is of concrete, and the walls of the well above the water surface are lined with buff brick, and finished at the top with a dressed granite coping 8 inches thick.

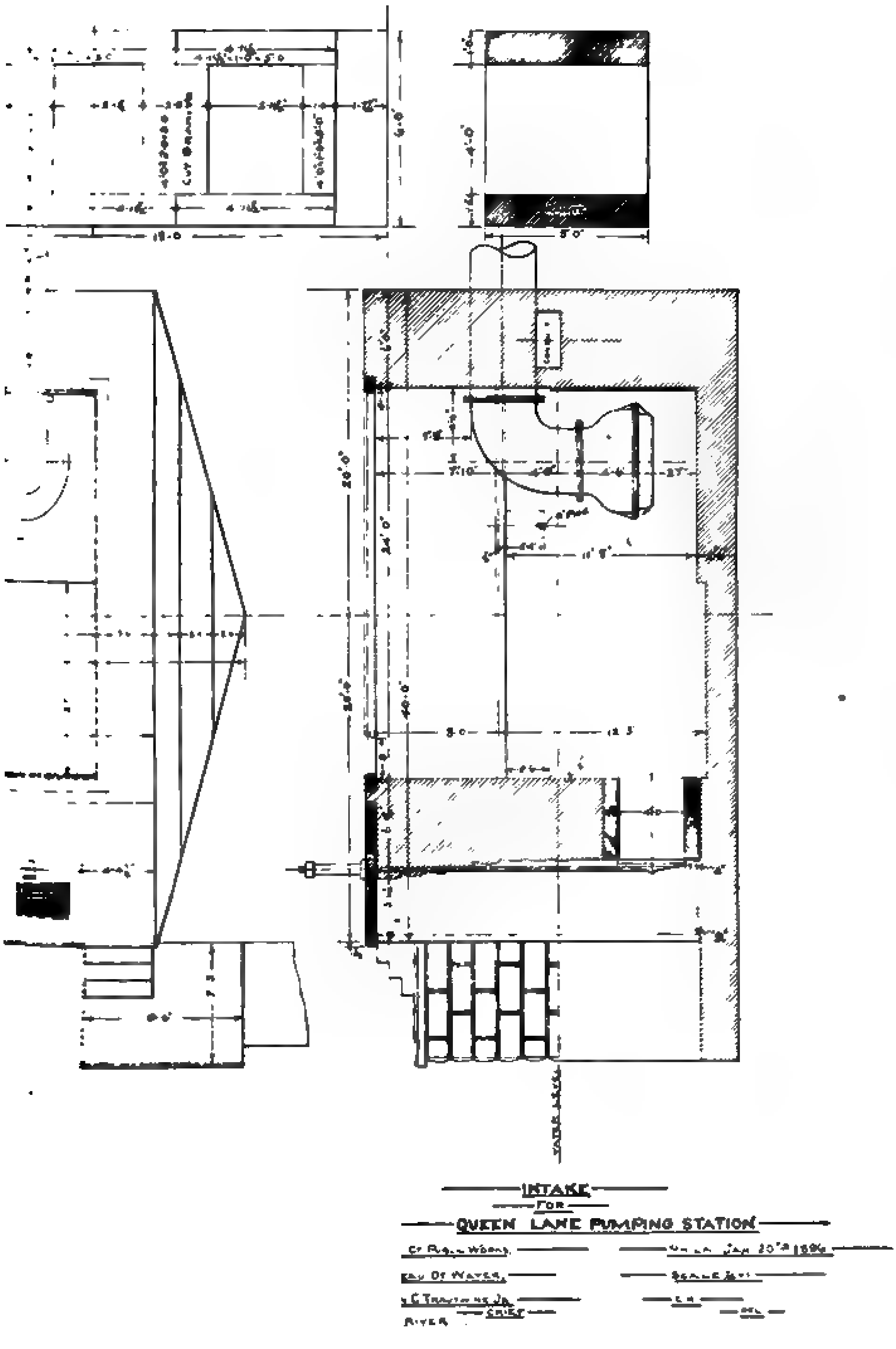
The excavation for this work was about 50 by 65 feet, and averaged 22 feet in depth, two-thirds of it being rock.

In order to do this work, which extended part way into the river, it was necessary to construct a coffer-dam, Fig. 3. This was made in the form of a triangle, with the apex in the river and the two legs resting on the bank. Three-inch pine, tongued and grooved sheathing, was used on the outside of the framing, and the latter was heavily weighted with stone to hold the dam in place. Very little trouble, considering the rocky nature of

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 4, January, 1897.]

Fig. 1.—Queen Lane Pumping Station and Intake.

Fig. 2.—Intake for



Pumping Station.

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 4, January, 1897.]

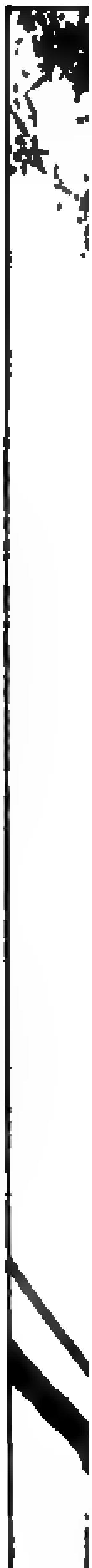


Fig. 8.—Cofferdam; Queen Lane Intake.

the bed of the river, was experienced from leakage, and none whatever with the additional dam which was afterward constructed in front of the first one, in order to make a channel, 45 feet long, to deep water, and thus insure the free flow to the intake.

From each of the wells two lines of cast-iron 48-inch suction pipes, with bell and bead joints, were laid to the engine house, one for each of the four 20,000,000 gallon engines. Each pipe is provided with a foot valve in the well and an air chamber at the pump.

No trouble was experienced from "ram," but, owing to defective caulking, the leakage at the joints was excessive, and it became necessary to uncover all the pipes in order to have them repaired. As an additional precaution against leakage, several coatings of asphalt were put on the outside of the joints, but the results are not entirely satisfactory.

Each of the 20,000,000 gallon pumps is provided with a 48-inch discharge pipe, arranged in such a manner that any one or more of the engines can pump through either of the two 48-inch pumping mains to the reservoir. The connections for these two mains are completed, and one pumping main, 7,267 feet in length, is finished and has been in use for some time. This main is 48 inches in diameter and is laid on a level from the engine house to Ridge and Midvale Avenues, a distance of 2,535 feet, from which point it ascends to Thirty-third Street and continues along the latter street to the reservoir, the whole line being constructed below the hydraulic gradient. The pipes from the engine house to Midvale Avenue are estimated to safely withstand a pressure of 112 pounds in addition to any increase due to ram. From Midvale Avenue the pipes are of less proportional thickness as the ascent is made to the reservoir.

When laying this main in Ridge Avenue, it was necessary to excavate nearly the whole space between the car tracks and curb from 8 to 20 feet deep, without interfering with the trolley cars or blocking the sidewalk. This was accomplished in the following manner:

Heavy timbers were placed across the trench at intervals of 14 feet, and stringers carrying T rails placed thereon. On this

track a tram car (Fig. 4) was run, having an overhead horizontal timber projecting at one end, to which a pulley was attached by means of which ½ cubic yard dump buckets were raised and lowered, the power being obtained from a crab-winch carried on the car.

To propel the car backward and forward, a crank, provided with sprocket wheels and link belts extending to corresponding sprocket wheels on the car axle at the rear end, was used. The method of operating was to raise the bucket when full, then run the car to a point where the pipe was laid, empty, and return. With medium runs, fifteen men, and not more than 15 feet depth of trench, an average of 250 cubic yards per day can be excavated by this method and dumped at the required points along the line, besides avoiding the annoyance of piling dirt on the sidewalk or street, and carting it therefrom. The machine was operated entirely by hand power, and it is particularly adapted for ditch excavation for water pipes and sewer work, especially in the populous and crowded parts of the city.

The Queen Lane reservoir consists of two sections, separated by a division embankment, and each section is provided with a stop house, from which there are two 48-inch outlets, extending into four lines of 48-inch supply mains. These four mains enter the Queen Lane distribution system at its northern extremity, necessitating considerable extension in order to connect them with the large pipes that previously supplied the district by direct pumpage at the lower end.

The objective points of the four mains are, first, Thirty-third and Master Streets, 17,000 feet; second, Twenty-ninth and York Streets, 9,680 feet (both of which are completed and in use); third, Broad and Dauphin Streets, 18,000 feet (nearly one-half of which is laid), and, fourth, Nicetown Lane and Germantown Avenue, 12,000 feet, of which only 1,915 feet have been completed.

Between Hunting Park Avenue and the reservoir, three lines of the mains and part of the fourth were laid in cuts ranging from 3 to 24 feet deep, and over a trestle 711 feet long, from 0 to 17 feet high. (Figs. 5 and 6.) A light rail track was laid over this portion of the line, on which the pipes were hauled into position for laying.

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 4, January, 1897.]

Fig. 4.—Apparatus used on Ridge Ave. for Excavating the Pipe Trench.

[Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 4, January, 1897.]

Fig. 6.—Trestle for Supporting Four Lines of 48 inch Mains.

Detector." To illustrate the results obtained with this detector, or, as we prefer to call it, the "Deacon Meter," I quote from my report to the Chief of the Bureau of Water, for the year 1892:

FIG 7.—DEACON WASTE-WATER METER.

"The waste of water is one of the most important matters in relation to the water supply, and should receive immediate consid-

eration. An inspection was made to ascertain the quantity of water lost by leakage from mains, service-pipes, or other appliances, and that wasted by allowing it to run unnecessarily.

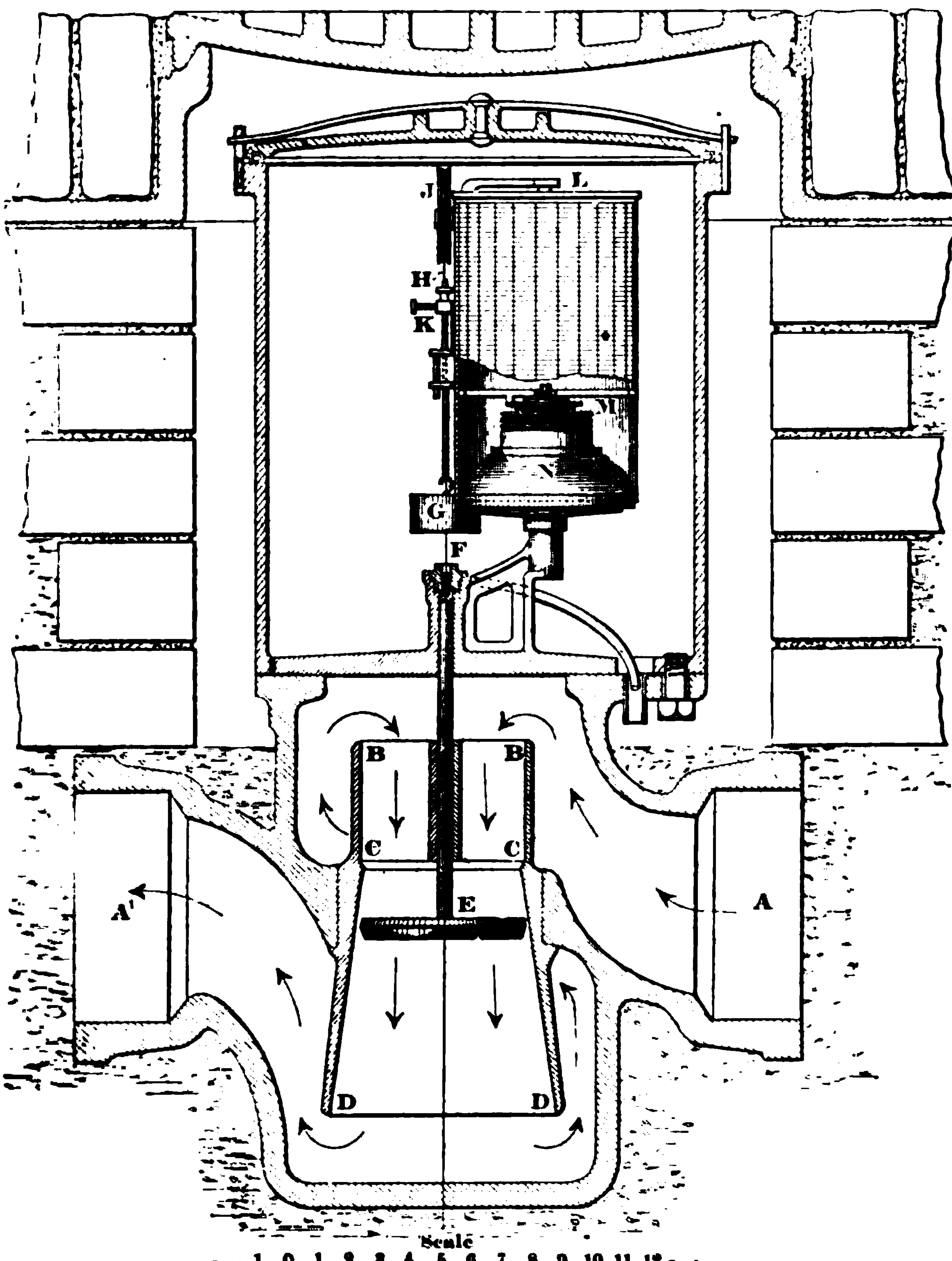


FIG. 8.—DEACON WASTE-WATER METER. VERTICAL SECTION.

"The locality examined was from Seventh to Eleventh Street, between Chestnut and Walnut, and from Eleventh to Broad Streets, between Chestnut and Spruce. The method of inspection

PLATE I.

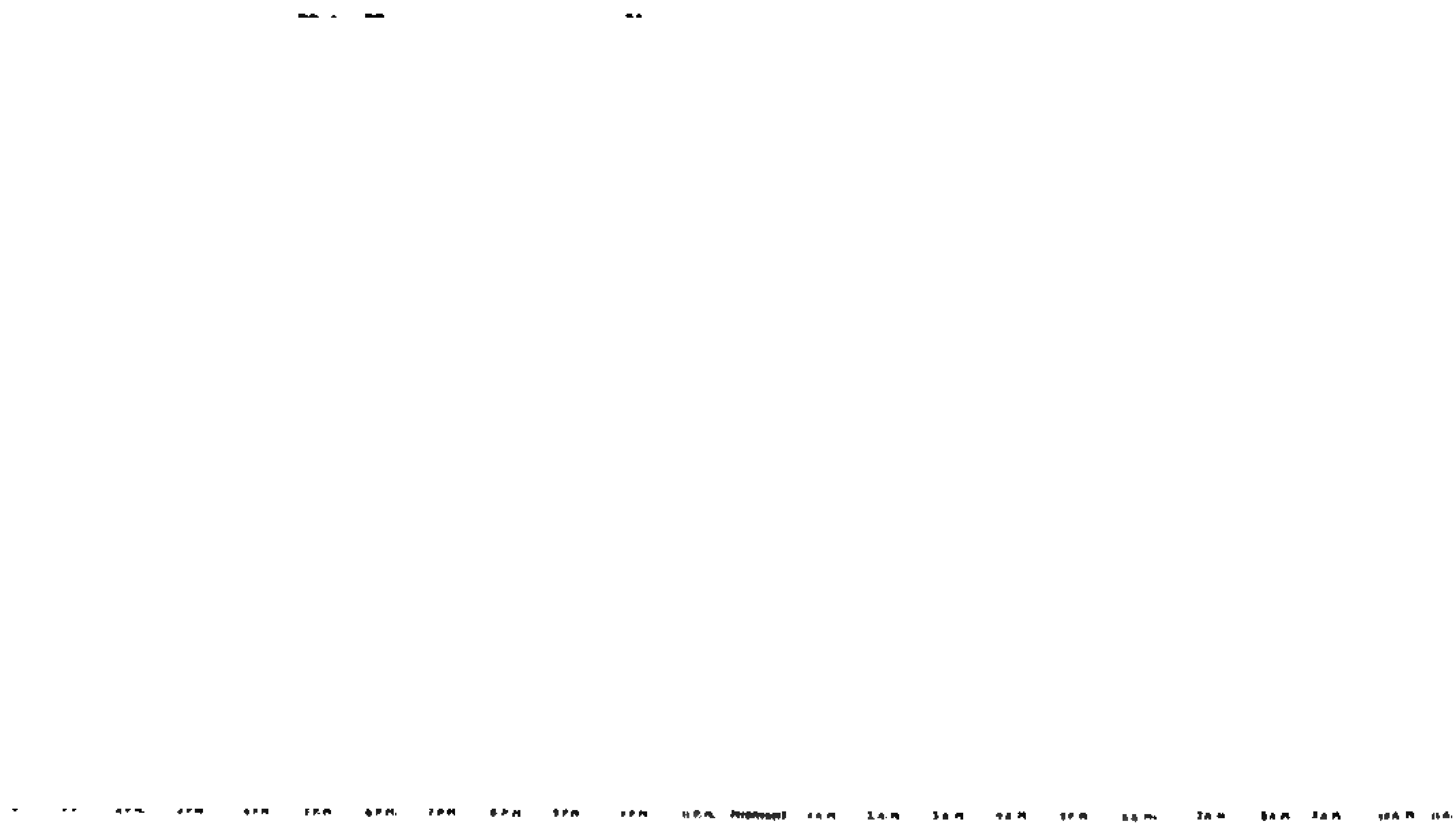


PLATE II.

PLATE III.

was to divide the above locality into the most convenient sections, and supply each section through a Deacon meter (Figs. 7 and 8), which is sensitive to the slightest variation in the quantity of water flowing through it, and records automatically on a diagram operated by clock-work the time and amount of every change.

"Plate I shows the total supply of a section for twenty-four hours, and is an instance where nearly the same quantity of water is used day and night, as shown by the irregular horizontal line at the top, indicating a very great waste of water.

"Plate II shows the supply of another section; but in this case a greater quantity of water is used during the day than at night, and may be classed as showing considerable waste, but not so much in proportion as in Plate I.

"After obtaining the total flow necessary to supply a section for twenty-four hours, as shown by Plates I and II, the several streets of a section were examined in the same manner, with the addition that the connections from the mains to the various properties were alternately shut off at the curb-stop, and if there was any water flowing at the time, a faithful record thereof was made by the meter, as shown in Plate III.

"The time for doing the latter work was from midnight until 6 A.M., when the least water was being used. On the day following the night of inspection the premises where water was found running were examined to ascertain the cause. In this manner the waste or leakage was discovered without annoying the residents, when unnecessary, by visits of the inspectors. The several street or night inspections were compared and checked with the twenty-four-hour diagrams, thus showing the total quantity used and wasted.

"Two tests were made to determine the accuracy of the Deacon meter, in comparison with other makes, the result being extremely satisfactory.

"The following shows the quantity of water consumed in the entire district examined:

TIME.	6 Hours. Gallons.	12 Hours. Gallons.	24 Hours. Gallons.
6 A.M. to 12 M.	350,520		
12 M. to 6 P.M.	359,160	709,680	
6 P.M. to 12 P.M.	321,160		
12 P.M. to 6 A.M.	285,320	606,480	
			1,316,160

which would amount to 480,398,400 gallons per annum, or 252 gallons per capita per day, of which 40.6 gallons are by meter.

"That portion of the area bounded by Chestnut, Walnut, Seventh, and Eleventh Streets, consumed water at the rate of 523 gallons per capita per day, while that within the limits of Spruce, Chestnut, Eleventh, and Broad Streets, uses but 179 gallons.

"Another examination was made to determine the quantity used on Spruce Street, from Eleventh to Thirteenth, which was found to be at the average rate of 63 gallons per capita per day. In this case there were no leaky appliances, and no waste other than that in connection with domestic uses; the properties in question being —with the exception of one boarding-house—all private dwellings. The average rate on Thursday and Friday was 54 gallons, while that on Saturday was 80 gallons.

"Examination of the whole area mentioned shows the following results:

Wasted.—Leaking	52,454,880
Running	165,248,640
Leaking and running	35,145,120
	252,848,640
Used and wasted	91,936,200
Used	74,267,280
	419,052,120

"In addition to the known waste, water was being *used,* during the time of examination, at a number of houses, where it was impossible to separate the quantity *used* from that *wasted.* It is

The President.—With increase of population do you find this waste is increasing also?

Mr. Fuller.—The consumption of water is intermittent, while water that is wasting flows continuously; the waste therefore increases the ratio of consumption and it will be greater in proportion to the population.

The average daily consumption in Philadelphia during 1895, was 212,000,000, or nearly 160 gallons per capita. The daily average during the month of greatest consumption was 230,000,000 gallons; this year it is at least 245,000,000 gallons, equal to 32,-666,666 cubic feet, or a body of water, one foot in cross-section, 6,187 miles long. The increased consumption this year is due principally to the additional supply to the northwest section from the new Queen Lane system.

(In answer to a question.) The Deacon meter is placed directly in the line of pipe, or on a by-pass. The construction is such that the water first ascends to the top of the meter and then flows down through a hollow, truncated cone. Within the cone there is a horizontal disk that may move vertically, and when raised to the fullest extent, the opening or annular space in the cone is closed. As the disk descends to the larger diameters there is a space between it and the walls of the cone, proportional with the movement of the disk, through which the water passes to the bottom of the meter, and thence to the outlet. From the upper side of the disk, a shaft extends vertically, to the end of which a fine wire is attached. The wire passes to the outside of the meter, through a stuffing box and from thence over a pulley to a counter-balance weight. A carriage, carrying a metallic pencil, is attached to the wire, moving vertically with each movement of the disk, the movements being registered by the pencil, upon a diagram attached to a drum which revolves once every twenty-four hours. The vertical movement of the disk is caused by the difference in the pressures at the inlet and outlet, which vary with each change in the flow; for each variation there is a corresponding movement of the disk, and upward or downward strokes of the pencil on the diagram. The latter is ruled with horizontal lines, which indicate the rate of flow, and with vertical lines to determine the time. Thus, the pencil lines on the chart

The diagrams showing cross-sections of Market and Chestnut Streets, emphasize a condition which our city authorities must sooner or later take cognizance of, viz., that the sidewalks are occupied to a considerable extent as vaults connected with buildings, thus giving property holders boiler or storage room for which they pay no taxes. Permission for this must be given by some one in authority, and the sooner the practice is abandoned the better it will be for the future of the city, for it may be desirable to utilize the sidewalks for electric light conduits, minor water and gas connections, etc. At present, in some of our prominent streets, sewers and pipes can only be laid with difficulty.

Without desiring to question Mr. Fuller's estimate of waste, which is evidently based largely upon absolute data, I think that a large proportion of what is credited for waste is due to the failure to deliver to consumers a considerable amount of water. We have in this city undoubtedly many instances of criminal waste, such as closets which are allowed to run constantly, bar-room troughs, through which the water is run continually, but for which a mere pittance of five dollars per annum (I believe), is paid, etc. I, however, do not believe that the Philadelphia Water Works have ever pumped 240,000,000 gallons in one day, or that the daily average consumption is 160,000,000 gallons. In the first place, the delivery of the pumps is overestimated, and as quite a number of those supplying the city have no definite stroke, they are credited with considerably more water than they actually deliver, a condition arising from the growth of a system of keeping records, and comparing these with records of other cities. When records are based upon the cost of 1,000,000 gallons raised one foot high, it is natural that in making reports the pumps should receive as much credit as possible. In addition to this shortage of reported pumpage we have the leakage from some thousand miles of water pipe, in which there are probably 600,000 joints, independent of house and minor connections, and leaks may develop by numerous disturbances of ground in constructing sewers, etc. Then, too, a leaky fire hydrant or a defective valve is not unusual. Much of this pipe and many valves have been in use for a number of years, and

have left for waste only that which is escaping from leaky fixtures, or from appliances which are never closed.

Mr. Chas. Hewitt.—Mr. Fuller refers to the waste in houses. Our experience in this city in the last three years in connection with electric traction, satisfies me that there is waste in the streets from leaky joints. In our work we find water far in excess of what would percolate from the street surface. On Eleventh Street we found certain manholes which filled up very rapidly, one where a little stream passed in all the time. When you take the sum total of all the water that leaks in that way, the amount which we find is great, and the amount which we do not find is probably far greater. There must be a large waste in that way that would have nothing to do with appliances.

Prof. Walter L. Webb.—When tests are being made and the houses are being gradually shut off, does the flow stop altogether when all the houses are shut off?

Mr. Fuller.—After turning off the service connection at the curb, the flow of water through the Deacon meter will cease unless there is leakage from the service-pipes in the street, or from the water main. We do not find many leaks of this description. In one instance a pipe-joint was blown out and the water was discharging into a sewer at the rate of 1500 gallons per hour; we also found a pipe broken vertically, and the water running into a sewer; altogether we have found three or four leaks of this description that might not have been discovered if we had not used the Deacon meter. I do not think it is possible that the leakage from our mains will equal one per cent. of the total pumpage. Most leaks of this kind will show on the surface, and in such cases the repairs are immediately made. The Deacon meter is exceedingly sensitive, and the slightest flow of water through it is sufficient to actuate the pencil and indicate on the diagram that water is flowing. If there is any flow it must be traced and stopped. The inspection is not complete until the flow through the meter ceases.

Mr. Hewitt.—A leak does not always show on the surface. In one manhole the water flowed through so that it squirted right out in a stream. I don't know whether the leak is repaired yet, but it did not show on the surface. We also had a leak on Brown

Street where the water percolated along the conduits. This was afterwards found by the Bureau, but, as far as I can recall it, it did not show on the surface. It was a two-inch pipe.

MR. FULLER.—(In answer to a question.) The variation in the temperature of our mains is so slight that I do not think it would produce any practical effect upon the joints. At the commencement of the winter season there is usually an increase in the number of leak complaints, but it does not follow that the leakage has just developed; it may have been going on for some time, and only brought to the surface by the freezing of the ground.

MR. JOHN C. TRAUTWINE, JR.—Mr. Birkinbine criticises the four lines of pipe, and I am bound to admit that it is open to objection; but I recall a case in New York where there are six or eight or more laid in one of the avenues. As to vaults under the sidewalks, the Board of Highway Supervisors has a regulation requiring persons to leave a considerable portion of earth over the vault and between it and the curb. As to our pumpage, no doubt it is overestimated, but I think not very greatly, as we make an allowance to cover slip.

XIII.

RAPID METHODS IN INSTRUMENTAL DRAWING.

By Prof. L. F. Rondinella, Active Member of the Club.

Read November 7, 1896.

Drawing has been called "the universal language," and though the author of this expression probably did not mean to include engineering drawing in his forcible definition, it will apply to that branch of the art as soon as the adoption of the metric system of measurements by this country and England completes the vocabulary by giving it a universal notation. The skill with which this language can be written and read, or, in other words, the facility with which instrumental drawings can be made and used, is as important a factor of success in engineering practice as is a good system of book-keeping in mercantile business; and in these days of contracts, when "time is money," it becomes essential that this early part of the engineer's work should be done rapidly as well as accurately. With this fact in mind the following suggestions are presented to the Club with the hope that they may be found useful to some of its members in the prosecution of their work.

Engineering drafting is largely mechanical work, and the instruments or tools which are used are, therefore, of primary importance. For their quality and accuracy the draftsman must depend largely upon the reputation of the firm who makes them, but for improvements in their design his own appreciation of the value of labor-saving machinery should lead him to invent or adopt new devices that will enable him to do his work with equal or greater accuracy and in less time than by former methods. Unfortunately, however, draftsmen as a class are very conservative workmen, and are slow to see the need or advantages of new and improved instruments or methods. An illustration of this may be found in the fact that while for many years it has been customary with the best machine shops to use the inch for the unit of linear measurement, their draftsmen have been satisfied to use the architect's scale, which, while it

contains one set of graduations in full size inches, has all the divisions for reduced sizes with the foot as a unit. In using these scales, therefore, the machine draftsman either loses time by mentally changing his values from inches to feet-and-inches before plotting them on his paper, or else uses the foot unit to represent an inch, and the twelfths into which it is subdivided for plotting the fractions of an inch—with great possibility of error. In representing machinery "half size," since there are no "6 inches to the foot" graduations on the architect's scale as generally made, he must either use the last of the above methods or else divide all sizes by two and plot them as full size inches, with both loss of time and likelihood of mistake. It was the inconvenience which his students found in using the architect's

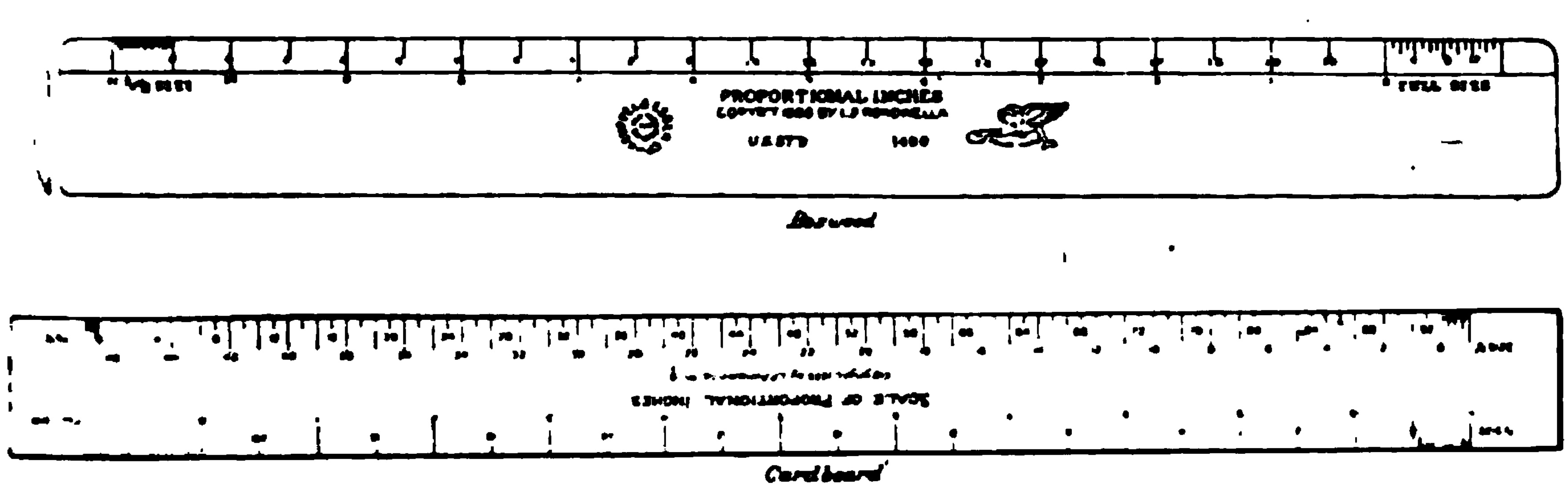


FIG. 1.—SCALE OF PROPORTIONAL INCHES.

scale for half size inch measurements, that led the writer to search for a proportional scale having the inch for a unit, and not finding a practical one, he devised the Scale of Proportional Inches, illustrated in Fig. 1. This is arranged exactly like the architect's scale (of proportional feet), but its purpose is entirely different. Its units represent inches, and the one beyond the zero point is, therefore, subdivided into sixteenths (instead of twelfths) to represent fractions of an inch. The method of using it for plotting inches and fractions will be self-evident to all who are familiar with the architect's scale for plotting feet and inches, and on drawings where all sizes are expressed in inches it will be found a great time-saver.

For measuring angles of *all* sizes, as the civil engineer is obliged to do in plotting his surveys, an accurate protractor is

necessary; but for convenience in construction, mechanical engineers and architects base polygonal forms on the equilateral triangle, the rectangle, the regular hexagon, and the regular octagon, and their draftsmen have usually plotted angles from right-angled triangles accurately made of sheet material, with the acute angles 45° x 45°, 30° x 60° and 22½° x 67½°. Those who have only the first two of these triangles can plot, with the aid of the T-square, all angles that are multiples of 15°, while those who have the third also, can plot all multiples of 7½°. As it requires very careful manipulation in combining two triangles against the T-square to form such angles as 15° or 37½°, and as it is inconvenient to have many instruments on the drawing board or to change frequently from one to another, some few attempts have been made to devise a single instrument to take the place of the first two, or of all three of the triangles above named, but the results have generally been too clumsy or expensive to be practical. The writer has spent considerable thought on this problem and has invented several forms, of which the best two have been in public use for some time, under the names of the Double Triangle and the Tetrangle. These are both quadrilaterals of hard rubber or transparent celluloid, having one or more inside edges made accurately so as to be used in addition to the four outside edges.

The Double Triangle, illustrated in Fig. 2, is for plotting all multiples of 15°. Two of its outside edges are at right angles to each other, and form the angles of 30°, 45°, and 60° with the two other outside edges, and the angles of 15° and 75° with the longest inside edge. During the past three years this instrument has been used by hundreds of students and professional draftsmen in place of the two triangles and has proved itself capable of doing their work in one-half or two-thirds the time.

The Tetrangle, shown in Fig. 3, is for plotting all angles that are multiples of 7½°. The sides of its right angle form the angles of 15°, 30°, 60° and 75° with the two remaining outside edges, and with one of the latter against the T-square blade the other makes the angle of 45° with it. The angles of 7½°, 22½°, 37½°, 52½°, 67½° and 82½° are formed by the three inside edges, as shown in the table of angles that is stamped on each instrument,

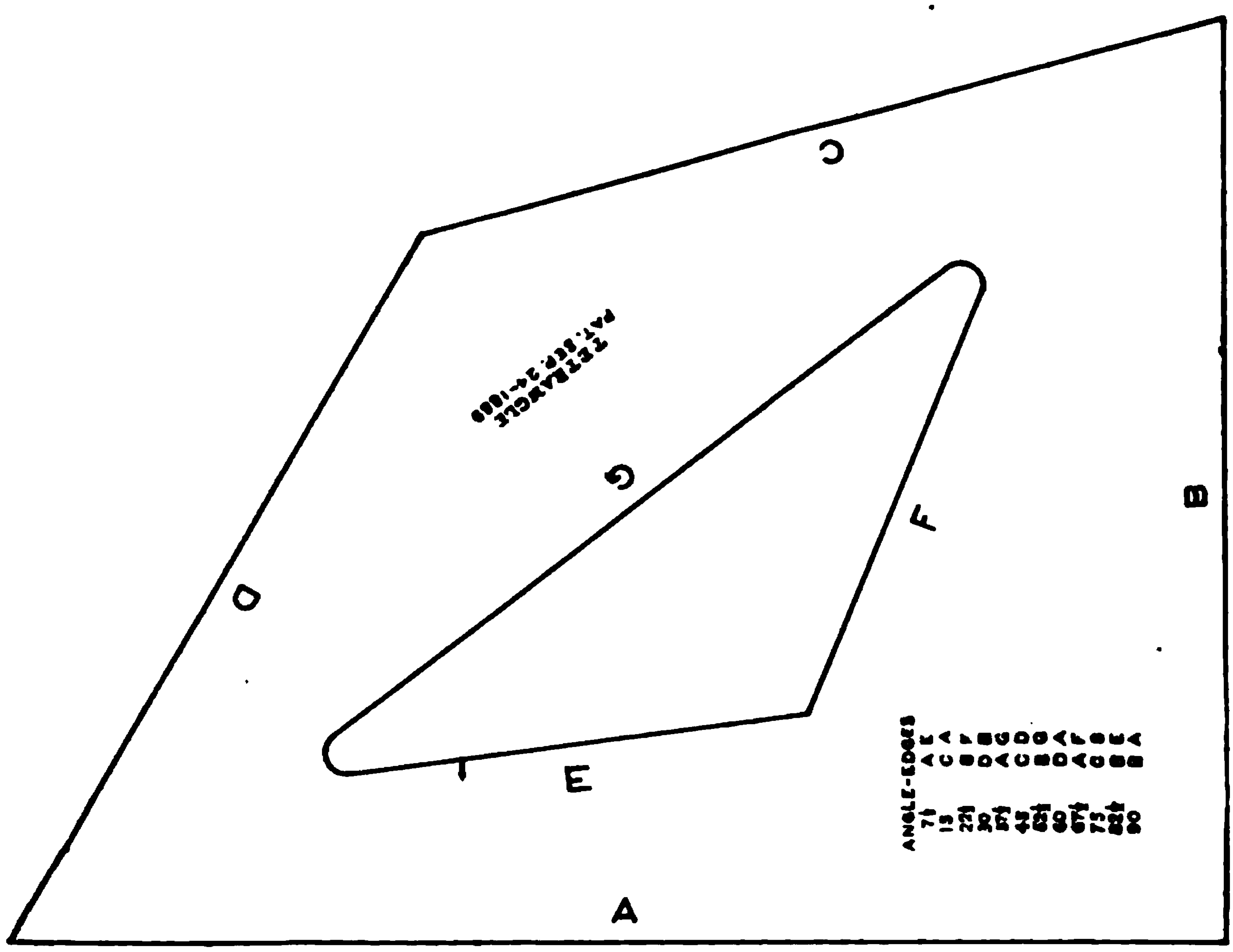


Fig. 3.—The Tetrangle.

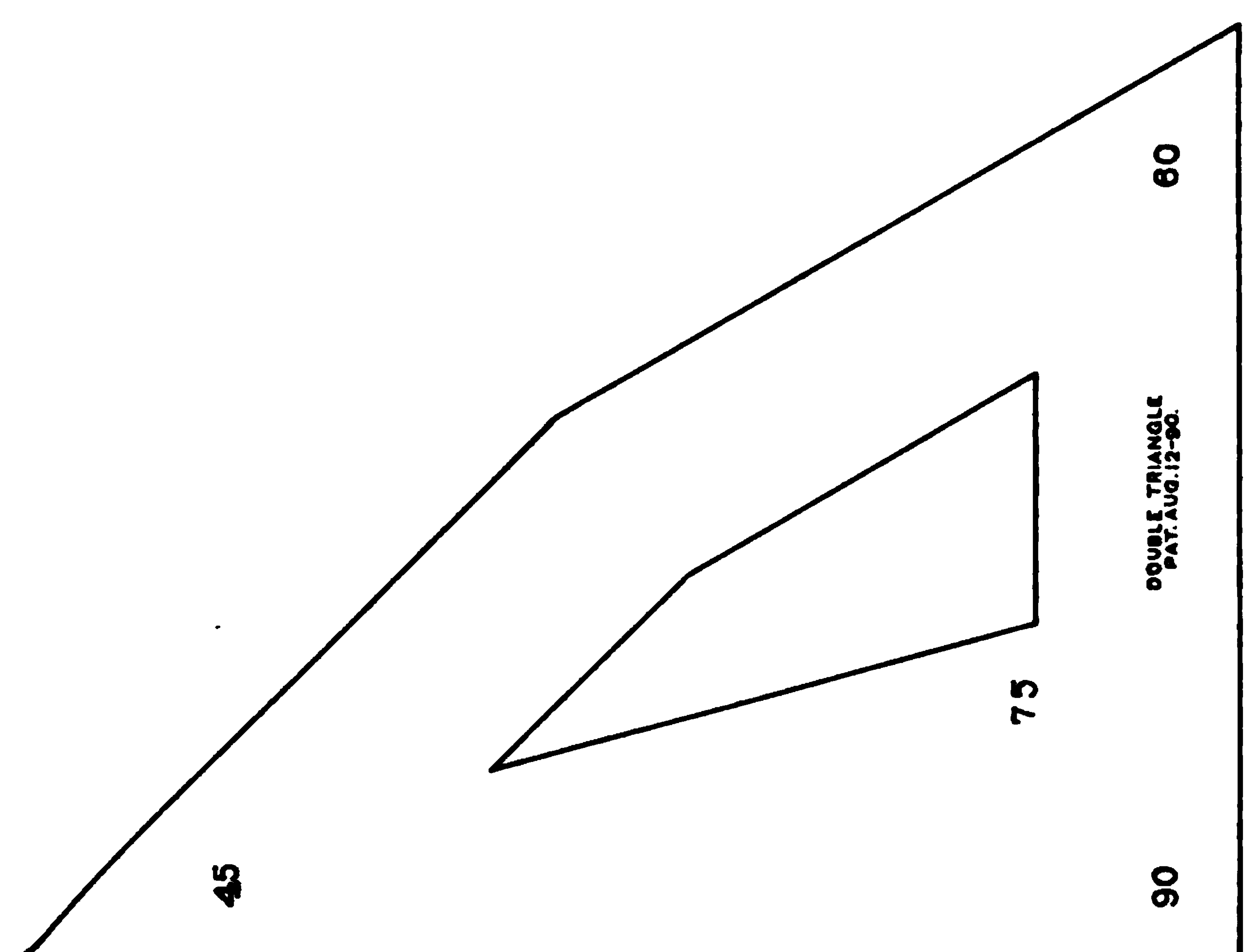


Fig. 2.—The Double Triangle.

as in the figure. The Tetrangle is especially convenient in architectural work and ornamental design.

Many draftsmen do not appreciate the time-saving value of cardboard scales and protractors. The former can be obtained with all kinds of graduations accurately printed upon good Bristol board, from machine-engraved copper plates, and they possess the advantages over boxwood scales, first, that they do not require to be flat on the paper throughout their entire length, and will allow other instruments to remain under them on the board, except just where measurements are being made; and second, that they change with the weather as the paper does, whereas with a boxwood scale, especially in large work, if some measurements are made for instance on a rainy day, they will be smaller on a dry day, and it is then difficult to work accurately from them. Cardboard protractors can be obtained in semicircles or circles up to fourteen inches in diameter, with accurate divisions to quarter degrees, which can be numbered to correspond with the system of readings taken in a survey. Used in connection with a cardboard scale as described below, such an inexpensive combination makes an instrument of greater scope and usefulness than the costly metal protractor with radial straight edge, to save the time of laying out courses before plotting measurements from each instrument station.

For use in radial measurement a cardboard scale should be selected with the desired proportional graduations on a perfectly straight edge, and may be prepared as follows: A knife-cut should be made from the blank edge about two-thirds across the scale at about one-quarter inch further in than the zero point, and the face of the cardboard should be scored from this cut to the end of the scale, forming a flap to be turned under and pasted to the back of the cardboard. When thus arranged, as shown in Fig. 4, a fine prick-point or needle can be pushed through the projecting part exactly at the zero of the scale, and may be driven through the drawing paper into the board, at the point where each instrument station is located, so that courses can then be measured directly from the edge of the scale.

The circular protractor should have a radius greater than most of the distances to be scaled, and the cardboard on which it is

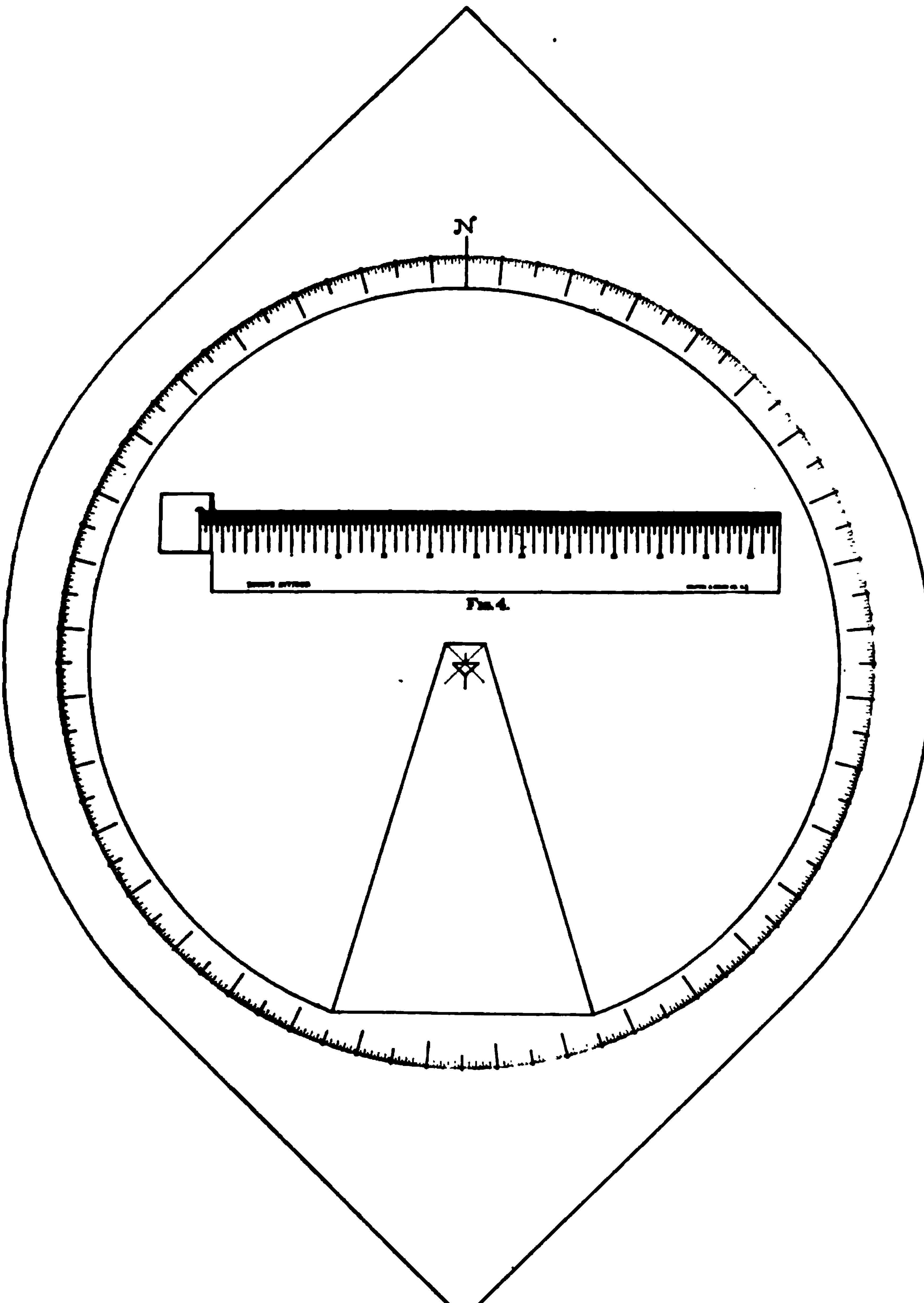


FIG. 4 AND 5.—FOR PLOTTING ANGLES AND DISTANCES SIMULTANEOUSLY.

printed may be cut to the outside shape shown in Fig. 5. Numbers should be marked outside the graduations to correspond to the numbering on the surveying instrument, commencing with 0° opposite one corner of the cardboard, and the inside should then be cut out as shown in the figure, leaving a segmental flap of about 20° opposite the zero point. In the blunt end of this, a little triangle is cut out, so that one of its sides passes exactly through the center point, and the face of the cardboard is scored across the base of the flap, so that it can fold under the circle of the protractor. This hinge may be strengthened by pasting a strip of tracing cloth or court plaster under it.

To use these two instruments in plotting topography notes, for instance, a line should be drawn northward lightly from the instrument station on the paper, and the protractor "set up" by making its center cover the instrument station with its zero point on the line. A weight is then put on the N. corner of the protractor, the opposite corner is lifted up so that the flap can be folded under, and a weight then put on it so as to hold the protractor firmly in place, and leave a clear open space around the instrument station on the paper. The zero of the scale is then set up at this point in the manner described above, and all the readings from that station can then be plotted as follows, greater speed being attained by an assistant reading off the notes while the draftsman plots them. First the bearing is read, and the scale is swung round till its straight edge covers that angle on the protractor; then the distance is read and marked as a pencil point at the corresponding division of the scale, which can then be turned out of the way. A small circle is now drawn around the point to indicate it more clearly; its topographical character, as stated in the notes, is marked on the paper by an abbreviation above it, and its elevation is marked below it, making the data for that point complete. All other readings from the same instrument station are then plotted in this way, ending with the reading to the next station; the protractor and scale are then moved, and set up again at the new point. If the proportional distance of any reading should fall over the cardboard of the protractor when the scale is at the proper angle, a straight line can be drawn lightly along its edge and the reading marked on it, so that when

respectively to the horizontals. To save the time and labor of laying out spaces for block letters, especially when letters are far apart or in curved lines (as often occurs in the names of land and water divisions on maps), only two parallel or concentric lines need be drawn for the total height of the letters with normals for the positions of their centers, and the letters can then be pricked through from a piece of block-ruled paper by transferring points for the ends of straight lines, and the centers and tangent points of curves. Thus, by placing a piece of square

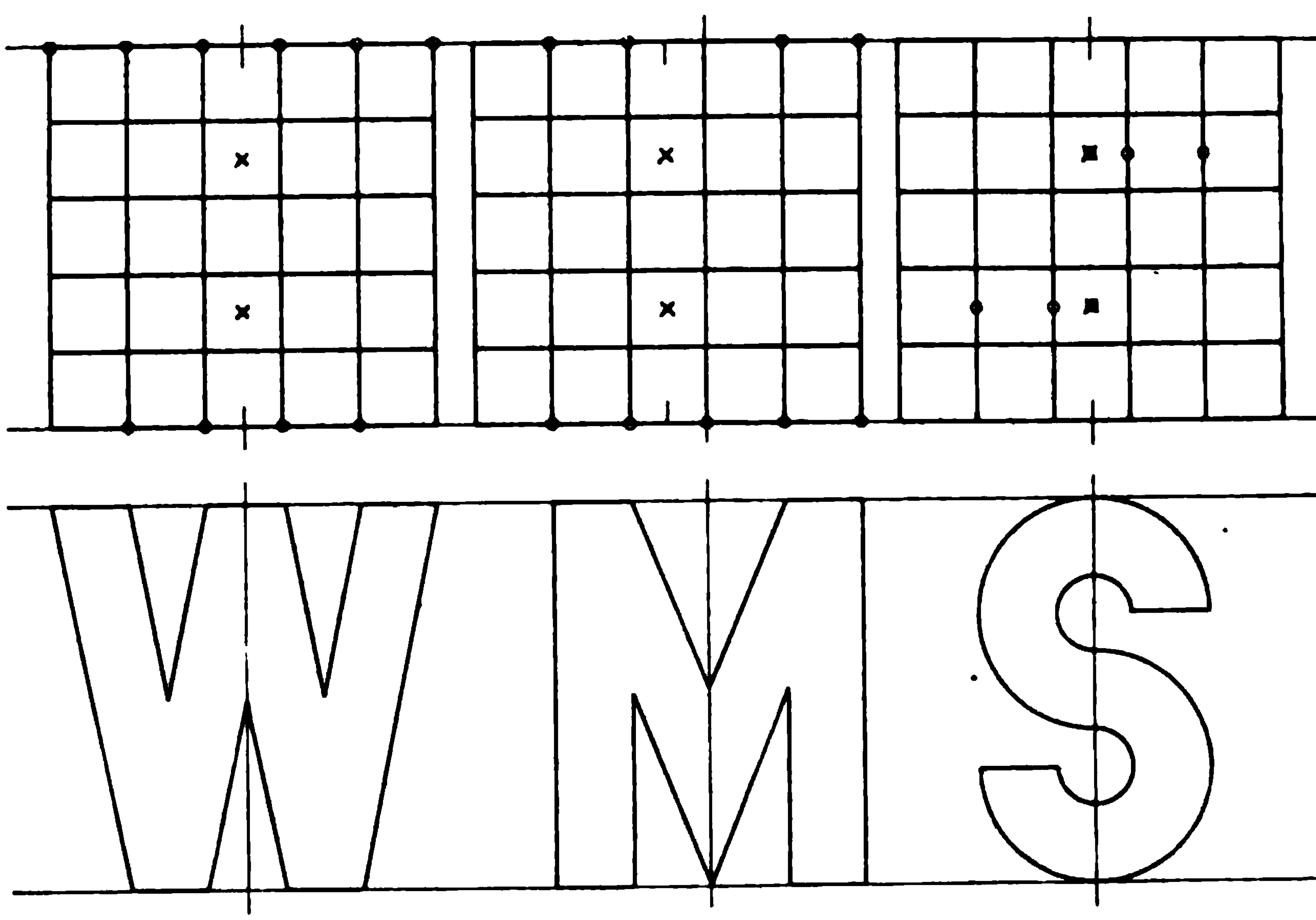


FIG. 8.—RAPID METHOD OF FORMING LETTERS.

ruled paper, as shown at the top in Fig. 8, and pricking through at the points marked by little circles, the letters W, M and S can afterwards be quickly drawn, as shown below in the same figure.

To make the cross-hatching on large section surfaces regular, without the aid of some spacing device, requires considerable time and experience, with strain upon the eyes; and though there are several excellent section-liners on the market, they are so expensive that but few draftsmen use them. A very good device, and one that has long been used in some drafting rooms, can be made out of a soft-wood straight-edge, about one-eighth inch thick (*e. g.*,

a penny ruler) and two pins, to be used with a triangle and against a T-square blade. One side of the triangle is placed against the upper edge of the soft wood on the paper, so that an adjacent side forms the angle desired for the hatchings, and the pins are driven into the edge so that the corners of the triangle can strike against them, the distance between the pins being equal to the side of the triangle plus the desired distance between the hatchings. To use this device, the lower edge of the soft wood is placed against the upper edge of the T-square blade, as shown in Fig. 9. With the triangle against the left-hand pin, a line is

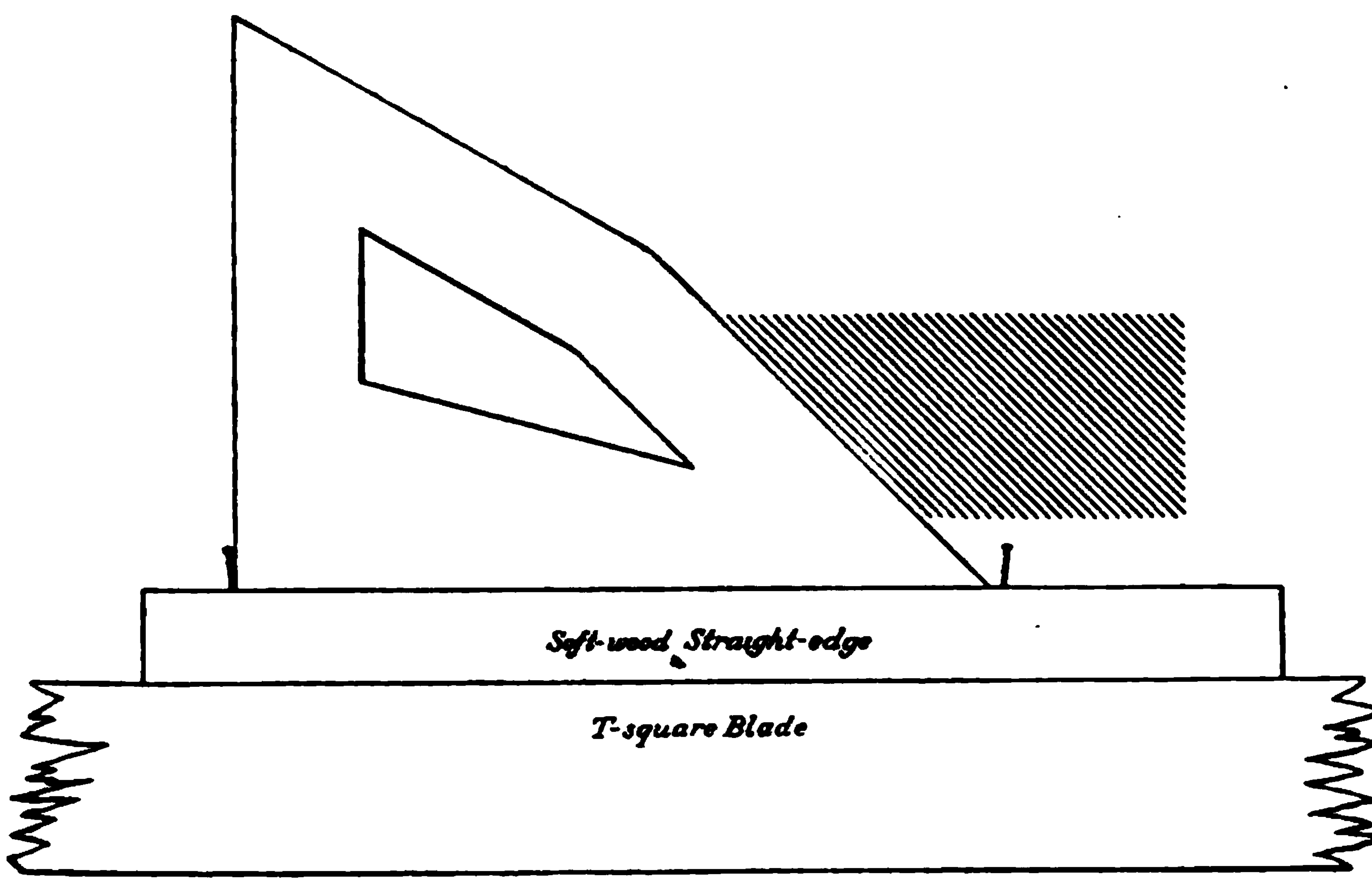


FIG. 9.—DEVICE FOR CROSS-HATCHING.

drawn along its right-hand edge; the triangle is still held firm, and the straight-edge is slid to the left until stopped by the right-hand pin; the straight-edge is then held firm, and the triangle slid up to the left-hand pin; a second line is then drawn, and this process is repeated until the section surface is covered with equidistant lines. After a little practice, work can be done very rapidly with this device, and the eyes are not strained to judge the distance between the lines.

In entering dimensions on constructive drawings, care should be taken to form the figures plainly, and not to put them where the dimension line is crossed by another line. In the opinion

and experience of the writer, a good deal of time can be saved in the drawing room (especially on large work) and afterwards in construction, by entering the figures in the dimension lines all in one direction, so that they all read (as the lettering should) from left to right parallel to the bottom of the paper. The usual method of making the figures always in the direction of their dimension lines is probably continued only by the powerful momentum of established custom; for as the difference in their possible directions is nearly 180 degrees, the draftsman must turn his arm, his body or his drawing to enter most of the figures, and the workman in using the drawing afterwards is almost sure to turn it into as many different directions to read them, which is certainly inconvenient. Putting the dimensions all one way not only results in a saving of time for the draftsman, but it gives the drawing a plainer appearance, and makes it easier for the workman to use.

In closing, the writer would emphasize the fact that while rapidity in the production of instrumental drawings is an important factor of economy, it should never be used at a sacrifice of accuracy and neatness. Responsible draftsmen or engineers in charge of irresponsible ones, should therefore see to it that they are using those methods and instruments, new or old, that will enable them to do their best work with the least expenditure of time.

DISCUSSION.

Maj. Wm. H. Bixby.—I have used paper scales myself for twenty years. They are exceedingly handy and useful, but they are specially liable to error from unequal expansion or contraction when wet or dried. Some twenty years ago I was working up a graphical table, requiring great accuracy, and made it by the aid of a paper scale. Nothing came out right on the first trial. On examination I found that the paper scales, after their manufacture, had been rolled up in packages of dozens or twenties, and the divisions on the inside of each roll were shorter than on the outside. The inside end of each scale had compressed and the outside had stretched, so that the divisions were too near together on one end and too far apart on the other. When you have some particularly careful work to do, you should specially test all paper scales against such error.

XIV.

PROFESSIONAL ETHICS AMONG ENGINEERS.

By Charles Piez, Active Member of the Club.

Read November 21, 1896.

Engineering societies play a very important part in the advancement of engineering science. In a profession requiring so broad a knowledge and so wide an experience, it is absolutely necessary, if the engineer wishes to achieve distinction, to keep in touch with what is going on around him. It is by facilitating the interchange of professional experience, by promoting the discussion of professional subjects, and by distributing among its members the information thus obtained, that the leading societies have made themselves factors in the progress of engineering. But the objects of the societies should not cease there. They should discourage and, if possible, suppress any practices among engineers which are not strictly in accord with the highest standard of ethics. To accomplish this it is not necessary to lay down laws for the regulation of the engineer's conduct in the exercise of his profession; for the same code that governs his social life will also obtain in his professional career. If it is wrong in the one to be dishonest, to lie or to steal, it is equally wrong in the other. His conceptions of right and wrong in his professional capacity cannot be modified to suit his interests, and excused on the ground of professional license. Unfortunately, the keenness of competition in business has had a tendency to develop practices which are but one remove from dishonesty, but which are nevertheless sanctioned and even lauded under the names of business sagacity and shrewdness. It is not surprising therefore if some of these practices have crept into engineering and have asserted themselves in some special and distinctive forms.

It is not my purpose to take up this evening the broad subject of professional ethics, but rather to confine myself to the discussion of one of the practices above referred to, which has become especially prevalent, and which demands rather heroic treatment

for its eradication. It is probably not too broad an assertion to say that every firm of engineers, or engineering contractors, has at some time been the victim of this practice. Let me mention an example. The engineer of a certain transportation company submits to several firms of contractors the problem of delivering merchandise from steamers and cars to a warehouse, and *vice versa.* There are special conditions: a large rise and fall in the tide; a considerable difference in the distances from the dock at which the vessels are moored, and a large variation in the size and weight of the packages. The engineer requests the bidders to submit detail plans and specifications, in order to better enable him to compare the bids and decide on their merits. The contractors, realizing the justice of the request, submit their plans and send representatives to fully explain them. The problem has been a difficult one, differing in its conditions from anything ever constructed in that line, and the solution has entailed considerable expense. The engineer, after inquiring into the minutest details, awards the contract to a bidder whose name in the trade is synonymous with poor work and low prices. One of the unsuccessful bidders, upon hearing of the award, and suspecting foul play, telegraphs for the return of the plans and models submitted. He receives in reply a letter stating that the plans had been sent back,—but the plans never reach him. Upon further investigation he is informed that his plans have been seen in the possession of his successful competitor, and when the plant is completed it is found to be a counterpart of the plans submitted. This case is not hypothetical, but has occurred within the past eighteen months. I have mentioned it as an example of a particularly aggravated form of this pernicious practice.

The offender in the above instance is an engineer of some prominence in his locality, and he no doubt considers his infamous action as an example of business sagacity and justifies an unscrupulous violation of professional ethics on the ground of having saved his client five or ten per cent. of the cost of the outfit. Were such examples rare, they would not merit recognition nor demand action for their suppression by the engineering societies, but the experience of every prominent engineering

concern is replete with examples of professional piracy, differing from the above case only in degree. There is no doubt that this offense is not considered a very grave one by the majority of engineers who commit it. They are led to it by self-interest, and are ever ready to satisfy a not over-active conscience by the spurious plea that ideas not patented are common property. We can conceive how such a notion could prevail among the laity, but cannot justify so gross a violation of professional ethics by engineers on so flimsy an excuse.

The most valuable assets of an engineer are experience, adaptability and inventive skill. They are gained only by years of special training, by close and continuous application, and are never acquired except at considerable sacrifice and often at considerable cost. They are the equivalent of a cash working capital, and their products should be regarded in the same light as the products of a manufacturing establishment.

The engineer—especially the engineering contractor—is placed at a considerable disadantage as compared with members of other professions. He is frequently called upon to submit solutions of problems in competition with other engineers, and is retained or awarded a contract only after he has demonstrated to his prospective client the practicability of his solution, or has proved its superiority over competing ones. In other words, he gives his prospective client the benefit of his skill and experience before he can expect even a promise of compensation. It is true that in some instances he can secure himself by obtaining Government protection through letters-patent, but this system is fraught with so many restrictions and with so much expense that it is available as a safeguard in but a relatively few cases. As a rule, therefore, the engineer is dependent wholly upon the good faith of his prospective client; and the latter is no more justified in adopting, without compensation, either the whole or a part of the plans submitted, than a merchant is in retaining, without payment, goods ordered on trial.

The very system which has been devised by the Government to protect inventors, has become a menace to engineers, for it has fostered the notion that all ideas not so protected are necessarily common property. This notion is wholly wrong and thoroughly unjust, for it denies to the products of mind labor, all the rights

which are vouchsafed the products of hand labor. It loses sight of the fact that skill and experience form the major part of the resources of all engineering firms, and that by appropriating the fruits of their skill and experience you are robbing them of a material part of their income.

So long as man is dominated largely by self-interest and so long as his conceptions of right and wrong are liable to be warped by selfishness, it is vain to hope that we can eradicate this evil without legislation. What we can accomplish, however, is to inculcate in members of our profession a proper respect for the sacredness of the ideas of others; and no agents can be so effective in bringing about this moral reform as the various engineering societies. Honesty is quite as essential a quality in an engineer, as knowledge and skill. His relations with his employer or client are based on good faith, and he must accord to contractors fair treatment. A high standard of ethics is in consequence absolutely necessary to the just discharge of his duties. It is therefore properly within the province of engineering societies to establish the code of ethics for the government of members and to enforce a strict adherence to this code.

The professional piracy to which this paper has been devoted is so prevalent and so destructive to the interests of honest engineers and the fair name of the entire profession, that it becomes imperative that the various engineering societies should recognize its existence and adopt summary measures for its suppression. Such action, to be effective, must be taken concurrently by the leading societies, and it would certainly be fitting for our society to take the initiative and present this subject to sister societies for consideration. Let us, by inviting a general discussion of this question, quicken the moral sense of the entire profession; let it be widely understood that the theft of an idea is as much a crime as the theft of a sum of money, and that the commandment, "Thou shalt not steal" is as essential a part of professional ethics as it is of Christian morality. Let the various societies adopt drastic measures for the punishment of guilty members. Such a campaign inaugurated against this practice would certainly result in an elevation of the standard of professional honesty, and would undoubtedly prove an effective step in the ultimate suppression of the evil.

submit a detailed plan with any proposition unless a condition accompanies it, that the plan, if used, will be paid for whether we get the work or not. We cannot wait until an engineer qualifies to pass a certain standard in order to get common honesty, but I do believe that you can insist upon compensation for plans used. Have it generally understood that the man who gives the contract is responsible for the use of the bidder's plans to the parties bidding. If the bidder stamped his plans as exclusive property, the other men will recognize the justice of it, and if the plan had been used, in nine cases out of ten, he will be willing to pay, but if you do not ask for it, I doubt whether you will ever get it.

Prof. E. Marburg.—The general question of professional ethics in engineering seems at times a rather discouraging one, and yet the outlook is made more hopeful by just such discussions as the one this evening. The greatly increased amount of attention that subjects of this nature have, of late years, received from engineering societies and from engineering journals, shows clearly that their importance is becoming better recognized. It should be borne in mind that engineering, as a profession, is of comparatively recent origin, and that high professional standards can be approached only by degrees. The history of the profession during the recent past shows much that is encouraging. The demands on the engineer have rapidly grown to be more and more exacting, and, with increased specialization, more scientific methods are brought to bear on the most minute details of his work. The need of a thorough technical education is appreciated to-day better than ever before.

The greatest difficulty in the way of the satisfactory adjustment of the many questions that come under the head of professional ethics, is the intense competition by which engineers are apt to find themselves confronted, or rather by the fact that this competition among engineers is more liable to make itself felt in certain objectionable ways than is the case in the older professions. It is hardly necessary to cite instances here, but it is doubtless true that engineers, not only individually, but as a class, are largely responsible for these conditions.

It would seem that the only course that engineering societies

may properly take in such matters would be to place their distinct disapproval on all practices of an unprofessional character, by discussions at meetings, by formulating codes, or by other such indirect means, all tending to bring about a healthier sentiment and a higher professional tone among their members. When openly dishonest practices, such as those mentioned this evening, have been committed, it would seem that redress should be sought in the courts, and that it would be expecting too much of engineering societies to undertake a formal investigation of such charges in individual cases, even granting that they had a right to assume such powers.

Mr. A. Falkenau.—I think this subject is one of the utmost importance to the engineering profession. A great deal of the immorality referred to is not practiced by members of the profession proper, but by commercial men. The tendency in this country is to pursue wealth solely without regard to any other higher standard, and this is liable to lead ultimately to serious results. I believe if the engineers as a body will use their influence, if they will uphold the high standards which they advocate constantly, if they will impress them upon those with whom they come in contact, the business men, and persist in them up to the point of resigning their position,—when we get engineers who will do that, for here is where the question of the dollar comes in with the engineer—when we find engineers declining to hold positions in an establishment which will stoop to any dishonorable methods, then we may hope to have an influence upon the commercial community.

Mr. Piez.—In the case to which I refer, the guilty person was not a financial man, but an engineer, a civil engineer and architect of some prominence, a member of the Society of Engineers and empowered with exclusive authority to sign all contracts. It is on that account I thought of bringing the matter before this meeting and have the Society take action. I think if we should attempt to lay down a complete code of ethics we will fail, but if we take individual cases like this in which there has been a flagrant violation of common honesty, the Society has a right to step in and put its mark of disapproval if nothing more severe on such action. If a man is guilty of dishonesty and theft he

has no right to be a member of an engineering society, and the Society itself has a right to expel him. It was that phase of the question I wished to bring up.

MR. A. FALKENAU.—It seems to me proper for the engineering profession to take steps to remedy these abuses. This engineering company, instead of considering the matter of cost or satisfaction, should have looked at the question as a moral one.

MR. PIEZ.—I think the engineering company in question is interested enough to push the matter to the extreme, but I hardly think that it is just to expect a single concern to bear the expense of raising the standard of the entire profession.

PROF. COMFORT.—I would like to call attention to the difficulty of bringing such a case under very rigid rules. It has been stated by one of the gentlemen that the reason they did not push the case was lack of legal evidence. Where legal evidence that would satisfy a jury is not known, it is very dangerous to go on circumstantial evidence, and, therefore, in expelling a member for unprofessional conduct on such grounds, we would have to use discrimination. Great care should be exercised in expelling a man from a society. There is no way to protect the legal profession from "shyster" lawyers; no way yet devised to protect the medical profession from "quacks," and I doubt if there is any way to absolutely protect the engineering profession from dishonest engineers.

MR. CHRISTIE.—If the members of the engineering societies would put a stigma upon a man who is guilty of unprofessional conduct, it would have a very powerful and potent influence in repressing these acts. It is a common thing for applicants for membership to the national engineering societies to be refused admission on account of being guilty of unprofessional conduct. Several engineers in high repute in this country have been refused admission to the Society of Civil Engineers on account of unprofessional conduct.

XV.

THE APPLICATION OF THE STORAGE BATTERY TO ELECTRIC TRACTION.

By CHARLES HEWITT, Active Member of the Club.

Read December 5, 1896.

THERE are three methods or forms in which the battery has, up to the present time, been employed in electric traction.

(1) The application of the battery on the car or locomotive.

(2) The application of the battery to long lines.

(3) The application of the battery in the power house itself.

While I desire, this evening, to invite your attention to some of the leading points in each of these three uses of the battery, I shall especially refer to the results of two applications which have come within my personal experience.

The Application of the Battery on the Car Itself.—The history of this use of the storage battery is a chapter of most remarkable failures. It is a strange fact that, in spite of the continued and unbroken series of failures, involving the loss of many, many thousands of dollars, that even to this day capital is quite readily obtained for continuing the experimenting in this line. But these experiments, although very costly, have had the effect of materially assisting in the rapid development of the battery, for there is scarcely any application of the storage battery which is so severe as its application to a car or locomotive. Some of these experiments have been very extensive, including the operation of a considerable number of cars, and sometimes of only one single experimental car. Some of the leading experiments have been with the Julien battery on the Fourth Avenue line, New York; with the Waddell & Entz on Second Avenue, New York; by the Metropolitan Traction Company, Washington, and on the Eckington and Soldiers' Home line, Washington. There was also an extensive trial made at Dubuque, Iowa. At the present time there is a road being equipped in Chicago, and there is also an experiment being made on the 34th Street branch of the elevated road in New York. This latter, however, is somewhat dif-

ferent in its application from the others, and I will refer to it later.

But very little reliable data is obtainable from all the various experiments that have been made; such information that has been given, is of a very general character, and is affected by enthusiastic imagination. A few trials have been made in England and on the Continent, from which, from time to time, data has reached us which seems to have been reliable. This data is largely in reference to operating expenses, and is, I think, unfavorble to the battery. All trials that have been made in this country have been at the expense and under the supervision of the storage battery manufacturers, and the data which they have undoubtedly obtained, seems to have been most carefully guarded. Mr. Dawson, in an article, published in *Engineering*, October 16th, says: "Two principal causes have so far prevented the successful use of accumulator cars; their great weight and rapid deterioration of plant. Owing to these causes, the manufacturers of storage batteries only have seriously taken up accumulator traction, and, although they have been working on the problem since 1880, little reliable information has ever been made public." These facts are my only excuse for presenting to you to-night the results of a test which I made some four years ago. I present the results of this test, not only for their own interest, but as a contrast to the more successful application of the storage battery, which I shall consider later on.

The essential features of a battery for use on a car are (1) a large capacity and light weight; (2) the ability to withstand heavy discharges without injury. The actual construction of this battery is not essential to the discussion to-night, but in order that you may better appreciate the results obtained, I beg to offer the following description:

The plates consist of a thin cast lead form; the form or conductor is enclosed in a rubber casing, which casing is punctured with many holes in the form of a truncated cone, the bases of the cone being against the lead conductor; these holes are filled with the active material. The objects of this form of construction are: (1) To utilize the lead simply as a conductor and not as a support for the active material, in order to reduce the weight. (2) To pro-

vide an elastic support for the active material to allow for expansion. (3) The plugs of active material being larger on the inside than on the exposed surface are held firmly in place. (4) No part of the plate subject to disintegration is exposed to the electrolyte.

As this battery was rather novel in its construction and seemed to overcome some of the bad features of previous forms of batteries, it was with a feeling decidedly favorable to the battery that I started to make this test, and I therefore cannot be accused of having been prejudiced against it.

The total weight of a cell averaged 28 pounds, made up as follows :—

Each lead form	10 ounces
" rubber casing	4 "
Active material, per plate	16 "
Total	30 ounces
11 plates at 30 ounces	330 ounces
Lead conductors, per cell	16½ "
Acid	85.6 "
Jar	28 "
Rubber fittings	4½ "

The active material forms 53 per cent. of the weight of each plate and 39 per cent. of the weight of each cell. There are 136 plugs of active material in each plate, and the total surface exposed to the electrolyte is 36 per cent. of the total area. These figures compare very favorably with other better-known makes of batteries. The total weight of a battery of 144 cells is 4,032 pounds.

This test was made on the Ninth Avenue Line in New York, running from 54th Street and Ninth Avenue to 125th Street, or Manhattan Avenue, a distance of nearly four miles. The road has numerous grades of 2 per cent., 3 per cent. and 4 per cent., and from Manhattan Avenue to 117th Street, a distance of nearly one-half mile, is a continuous rise of about 6 per cent., the track being in poor condition. The instruments used consisted of a Thompson recording meter, Weston volt and ampere meters, and a Boyer speed recorder. The regulation of the motor was accomplished by commutating the battery; or, in other words, by changing the

number of cells so as to vary the E. M. F. applied to the motor. As a consequence the voltage varied from 72 to 288, according to the load and the position of the switch. This is rather severe on a watt-meter, but the General Electric Company furnished one especially sensitive for this particular test.

The plan of taking records was (1) to discharge the battery through a liquid rheostat, in order to calibrate the instruments. (2) A speèd recorder was attached to the car axle, and a record taken of every movement of the car, giving the exact distance traveled and the speed at every point of the line. (3) Watt-meter readings were taken for every charge and discharge, and the exact time consumed for the first trip. (4) Simultaneous volt and ampere readings were taken at intervals of ten seconds during the first and second trips, and at one-minute intervals during two charges. (5) A final discharge through a liquid rheostat at a rate about the same as the average rate of discharge during the trip. Volt and ampere readings were taken every minute, and the open circuit E. M. F. every 15 minutes. A watt-meter record was also taken. I have plotted one of these sets of readings, which is shown in Fig. 1. These readings were taken every ten seconds, and it is assumed that each reading is the average for the ten seconds; the curve, therefore, shows a somewhat rectilinear form, but is more satisfactory to the eye, and quite as accurate as the curves which attempt to show the actual fluctuations.

The point to which I especially wish to call your attention in this diagram is the rapid fall in E. M. F. on heavy discharge. All storage batteries made for stationary use, or use on the car, show a drop in the working E. M. F. when the volume of current flow exceeds a certain amount per unit area of plate; this amount varies somewhat in different forms of cells, and the important point which I wish to bring out here is, that it seems impossible from the nature of the conditions existing on a car, to make a cell with a sufficiently large area of plate to withstand the heavy discharges without loss of E. M. F., and at the same time to be sufficiently light to be carried on a car. This falling off of E. M. F. is especially noticeable on the 6 per cent. grade, where you will notice the voltage falls directly in proportion as the

amperes rise. This fall in E. M. F. has a very serious effect upon the efficiency of the battery, as I shall show later. Six trips were made from 54th Street to 125th Street and return, and the battery was charged after each trip. The first five trips were made at such speeds as we were able to make between the horse cars without making unnecessary stops. During the sixth trip, stops were made at every third or fourth block in order to imitate a car in actual service. The seventh trip up was made to 117th Street only, but in this case two runs were made without

Fig. 1.—Battery Car Record.

recharging; this trip does not include the 6 per cent. grade, and was made in order to see what difference this would make upon the capacity of the battery. In all, the car made over sixty-two miles, at an average speed of only eight miles per hour. The maximum speed obtained was twelve miles per hour, which, compared with trolley cars, is very low. The E. H. P. per car mile was found to average 1.07 for the trips including the 6 per cent. grade, and .8 for the trip not including the 6 per cent. grade; this is about what I should expect to find with a trolley car of the same weight. The batteries were always

charged immediately after a run, and after standing over night they were found to have lost so much as to make an extra charging necessary. This loss on standing has been noted by all writers on storage batteries, and is probably due to local action of the battery itself, and partly to surface leakage. The loss is indicated by the loss of E. M. F. on open circuit. The average E. M. F. per cell at the end of the main charge was 2.35 volts, and after standing over night this had fallen off to 2.09 volts per cell; this is a well-known trait of all lead batteries, but it affects the efficiency of the cell considerably.

The total watt-hours consumed in charging and the time were carefully noted, as well as the watt-hours output and the time; from this we derive the following important results:

Total watt-hours *output* divided by the watt-hours *charge*, shows an average useful efficiency of only 44 per cent. for the trips, including the 6 per cent. grade, and 45 per cent. for the trip not including the 6 per cent. grade. The ampere-hour efficiency generally referred to by storage battery manufacturers, has been calculated approximately and shows 64.7 per cent. for the trips including the 6 per cent. grade, and 64 per cent. for the trip not including the 6 per cent. grade. These results show that the battery is not only very inefficient, but also that its efficiency is not much affected by the 6 per cent. grade. These figures show that even on a comparatively level road we could not expect a much better useful efficiency, but a car would make a greater number of car-miles on one charge. Undoubtedly the low efficiency is largely due to the extra charge and the overcharging, but if cars were run in actual service, either the batteries would have to be kept under a continuous charge when not on the car in order to prevent loss by local action, or else they would have to receive an extra charge before being put into service. We will not go so far astray, therefore, if we accept these figures as indicating what we might find on a regularly equipped road.

The following shows approximately the losses and efficiencies which might be looked for: Loss in engine and dynamos, 15 per cent.; this can only be obtained with direct connected units; loss in batteries, 50 per cent.; this is 6 per cent. better than that shown in the above record; loss in motor and gearing, 25 per cent. of

the power delivered to the motor. The total efficiency therefore, from the indicated power in the engine to the power delivered to the car axle is 32 per cent.

From these results I find also that for each hour of run, including the 6 per cent. grade, 2½ hours charging are necessary, and not including the 6 per cent. grade, 1.43 hours are necessary. This has a very practical bearing, as it means that in the first case at least an average of 3½, and in the latter 2.43 complete sets

FIG. 2.—BATTERY DISCHARGE THROUGH RHEOSTAT.

of batteries must be maintained for each car. Undoubtedly on a regularly equipped road this could be improved, but granting an improvement of 15 per cent., it would require two hours charging for each hour of run in the first case, and about 1¼ hours in the second case; so that at the very least, three sets of batteries would have to be maintained in either case.

I would next call your attention to the average power required in charging, which I find to be a little over 8 E. H. P. Taking an average of 8 E. H. P. required at the battery, and two batteries

per car undergoing charge, and allowing 15 per cent. loss in engine and generator leads, we find we will require an average engine output of 18.8 H. P. per car. For ordinary trolley roads 10 to 12 H. P. is the rule. For this battery the output of the station per car mile will vary from 1¾ E. H. P. hours to 2¼ E. H. P. hours; whereas, for trolley cars the output seldom averages over one E. H. P. hour per car mile. Mr. Dawson, in the article before quoted, gives the following data: Power per car mile required at power house, Paris, with lead batteries, 1.5 E. H. P. hours; Berlin, with lead batteries, 1.44 E. H. P. hours; Vienna, with copper zinc batteries, 1.71 E. H. P. hours. It will be seen, therefore, that the battery car, even on a regularly equipped road, will require at least 50 per cent. to 75 per cent. more H. P. hours than are required by a trolley car.

In order to get some idea of the capacity of the battery for doing work, I discharged it through a liquid rheostat at about the averge rate of discharge while running a car. Volt and ampere readings were taken every 15 minutes and 1 minute of rest was allowed; these readings were plotted and are shown in Fig. 2. The discharge was stopped, as you will see, when the open circuit E. M. F. had reached 1.7 volts per cell; beyond this point the pressure would have fallen off very rapidly. The results show an average E. M. F. of 253 volts; current 24.4 amperes; total time 2 hours 13 minutes; deducting 9 minutes for rest we get the actual discharges in 2 hours 4 minutes.

Taking the E. H. P. hours required to run a car as .8 and 1.07, as already shown, we find that the battery would run the car from 18 to 22 miles according to the contour of the road.

I would call special attention to the difference between the working E. M. F. and the E. M. F. on open circuit; this represents a direct loss. The charging curve, if shown on this same diagram, would begin at the same point, two volts per cell, and gradually rise until about 2½ volts per cell was reached. You will appreciate, therefore, the remark made by Sir David Salomon, "that it takes power to get the current through the battery, and that it also takes power to get the current out," both of which represent a loss in efficiency.

I may be open to criticism for attempting to draw conclusions

again. While on the trolley portion of the road, the batteries are being continually charged, there being only 200 cells on each car makes this possible, as with an average pressure of 500 volts on the line, the batteries would receive a pressure of 2.4 volts per cell, which is necessary for a complete charge. This has the effect of loading the feeder wires by just the amount additional which the battery will take, which will also decrease their efficiency. From the latest reports obtainable the whole arrangement appears to be a makeshift, due to the local conditions, and that the companies operating these batteries are in hopes that in the near future the city authorities will allow the overhead wire over the entire road, thus doing away with the batteries.

The short life of the positive plates has been a great drawback to all forms of traction batteries. There is no doubt in my mind but that improvements in the recent batteries have greatly lengthened their life, but there is no evidence obtainable to show that the efficiency is any greater than 1.1 to 1.2 K.W. hours per car mile on a fairly level track. This is the result of considerable experience on European roads, and corresponds closely with the results found in my own test. Officials of a storage battery company in this city inform me that they are now making plates which will have a life of at least 50,000 car miles, which, at 125 miles per day, is equivalent to 400 days, or a little over a year. The best life that I can find from published records show a life of about three months, and I have heard of tests where the plates have lasted six months. I think that I may safely assume that at the present state of the art storage battery traction will cost but little, if any, less than horses, and considerably more than the so-called trolley method.

In Mr. Dawson's article in *Engineering* I find the following table of comparative costs in Paris, per car mile:

	Cents.
Horses	17.1
Accumulators	16.66
Hot Water Locomotion	10.78
Trolley	9.24

This latter figure is approximately the average cost for trolley cars in this country. I think we are safe in assuming that the other figures will show a fair average.

The Application of Storage Batteries on the Ends of Long Lines. In such applications the conditions are entirely different. The battery in this case acts essentially as a pressure regulator. The conditions do not restrict the size of the plates, so that the plates can admit of such a size that the current density on discharge per unit area of plate can be kept well within the limits of normal discharge; and in consequence of this, the battery is not subject to the great loss of efficiency, due to the fall of E. M. F. on discharge.

Only a few such installations have been made, two of which are on the Isle of Man; one has been installed by the Anaconda Mining Company at Butte, Montana; there is also a small plant at Merrill, Wis. The first installation, however, that has been made for any large city road for its surburban service, I find, is the one installed by the Union Traction Company of this city at Chestnut Hill.

A glance at the map will give you some idea of the length of this line, with which undoubtedly you are all familiar. The history which led up to the installation of this battery may be of some interest.

The road was originally a horse car line which ran as far as the depot at Pelham. Conduits and cables were installed for operating a number of cars which were supposed to be amply sufficient. The phenomenal increase in the travel, however, necessitated a large increase in the car service. In addition, the success of the line warranted its extension to Chestnut Hill, and, as you probably are aware, the service was extended as far as Chestnut Hill Avenue, which is at the top of the long grade descending into the Wissahickon Valley. More recently the line has been extended down this grade to Hillcrest Avenue, and from Hillcrest Avenue to the Wheel Pump on the Bethlehem Pike. With the first extension of the line to Chestnut Hill, the underground cable was also extended, but the drop in pressure over this long line made it impossible to run the requisite number of cars, as the speed of a trolley car is approximately in the direct ratio to the applied E. M. F. The cables for feeding this section consisted of one cable extending to Chestnut Hill, one to Chelten Avenue and one to Wayne Junction about five miles from the

station; all these cables were 1,000,000 circular mils, copper, rubber-covered and leaded, laid in terra-cotta ducts. The investment in feeders for this line had reached a point considerably above $100,000, not including the ducts. To have increased the cable system so as to have supplied this section properly would have required about seven cables of 1,000,000 circular mils, and

FIG. 3.—VOLT-METER CHART TAKEN AT CHESTNUT HILL BEFORE THE BATTERY WAS INSTALLED.

of 48,000 feet each at $1.05 per foot, laid, which would amount to $352,800; deducting the value of cables three and seven, which were already laid, and which are estimated at $79,000, we find that the extra cost for cables without conduits would have been $273,800; this figure is, of course, prohibitive.

In order that you may appreciate the condition of the line previous to the installation of the battery, I would call your attention to Fig. 3, which shows a recording voltmeter chart taken at Chestnut Hill, and to Fig. 4, which shows the pressure at station bus bar on the same day. The question then resolved itself into the necessity of building a station, or providing some other

FIG. 4.—VOLT-METER CHART TAKEN AT BEACH AND GREEN ST. POWER HOUSE.

means of keeping up the pressure. If a station had been built at that point, it would of necessity have been small and inefficient. From records taken at the main power house, we found that it would be necessary to provide a station of about 750 K. W. capacity; such a station would have cost about $85 per H. P.,

or a total of $85,000. A battery station, on the other hand, required but little real estate, and would be inexpensive to operate, its cost would be considerably less than a power station. In the Chestnut Hill plant the entire cost of real estate, battery and building was approximately $25,000; to this must be added the cost of a booster in the main power house. We found that this required a 200 K. W. generator, which with its engine would cost about $8,000. The total cost of battery and booster would, therefore, have been $33,000. In this installation, however, we simply adapted a 500 K. W. generator at our Beach Street power house to this service, so that although we lost its service for 500 volt work, we were put to but little extra expense in the power house for adapting it to booster purposes. We find, therefore, that deducting $33,000, the cost of the battery and booster, from $85,000, the cost of a station, that the difference in

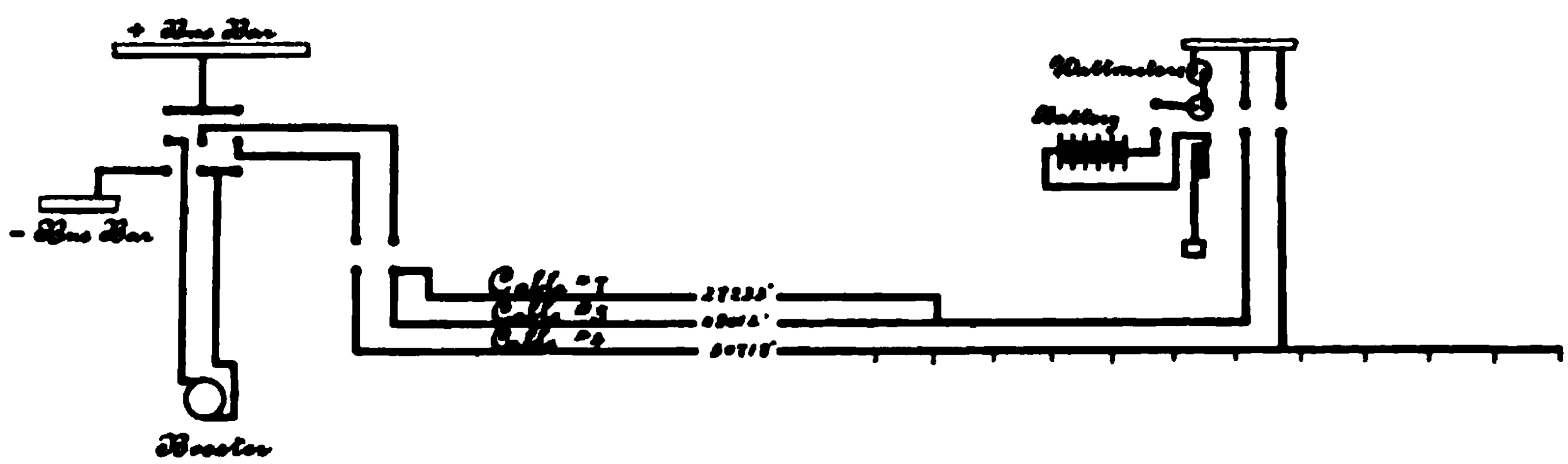


FIG. 5.—DIAGRAM OF CHESTNUT HILL CABLES.

first cost is $52,000 in favor of the battery. In addition to this, we were put to an expense of a little over $13,000 for changes in the cable. In the estimates that follow I do not include any cost or interest on the cable, as the investment would have been about the same whether we had built a station or installed a battery. It is very apparent, therefore, from the facts given, that on the score of first cost, the battery was by far the cheapest installment which we could make. In order that you may better understand the results which I propose to give in reference to the operation of this battery, I beg to describe the plant somewhat more in detail.

You will see by Fig. 5 there are three cables concerned in this work, which we have numbered No. 3, No. 4, and No. 7, all of 1,000,000 circular mils capacity; the lengths of these cables

are shown on the diagram. Cable No. 4 is the only one which supplies the trolley wire direct; or, in other words, all the taps from the underground cable to the trolley wire are tapped on cable No. 4; this cable runs all the way from the bus bar at the Beach and Green Street power house to the end of the line on the Reading Pike at Chestnut Hill. It feeds all of Germantown Avenue from Wayne Junction, and also the line on Chelten Avenue, making in all about 12 miles of trolley wire. Cable No. 3 runs direct from the Beach and Green Street power house to the bus bar at the battery house, as shown in the diagram. Cable No. 7 simply augments the capacity of cable No. 3.

In ordinary operation the current on cable No. 3 passes through the booster at Beach and Green Street power house, by which the initial pressure is raised 150 volts more or less above the ordinary bus bar pressure of 530 volts. By this means the drop in the cable is overcome, so that we are able to adjust the pressure at the battery house to a point where the battery varies but little to each side of the zero point, or, in other words, it charges and discharges continually, maintaining the load on cable No. 3 nearly constant, and consequently maintaining a constant E. M. F., where the current passes out from the battery house through cable No. 4, as shown in Fig. 5. This cable (No. 4) is therefore fed from two points, namely, from the Beach Street end at 530 volts, and from the Chestnut Hill end at a little above 500 volts. As a consequence, the distribution along the line from Wayne Junction to the end at Chestnut Hill is comparatively uniform, and is now very satisfactory. Fig. 6 is a copy of an average volt-meter chart after the battery was installed. When the load on the line is low, the current going over the cable No. 3 to the battery house, divides at the bus bar, one part supplying the necessities of the line, the other part charging the battery. When the demand on the line is heavy, the pressure drops a little at the battery house; all the current going over cable No. 3 will pass out over cable No. 4, and in addition, the battery will discharge sufficiently to make up for the extra demand for current. This has the effect, as I have stated above, of keeping an almost constant load an cable No. 3. After several months' experience with this equipment, we have found that at times the load on cable No. 3

has become so heavy as to reach the maximum pressure which the booster will generate. With the speed at which we are now running the booster, this maximum is about 250 volts; at such times, by an arrangement of switches at the Beach Street power house, shown in Fig. 5, we throw cable No. 4 on to the booster as

Fig. 6.—Volt-Meter Chart from Battery House after the Battery was Installed.

well as cable No. 3. In doing this, we increase largely the current through the booster, but are enabled to reduce the pressure to about 125 or 130 volts, and, in addition, get better pressure at the Wayne Junction end of the section.

I had expected to present this matter to the Club next March,

at which time we would have had more complete records; but the following data, which is the result for the operation for the month of October, 1896, will probably answer all purposes.

First, as to the cost of operating. From volt and ampere meter readings, taken from the power house at Beach and Green Streets, we find that 136,576,919 watt-hours were delivered to cable No. 3. By watt-meter records at the battery house, 1,728,000 watt-hours were lost in the battery, leaving a difference of 134,848,919 watt-hours delivered to the line at the battery house. These figures, I may explain, do not include the watt-hours generated by the booster, since we have assumed that this entire amount is lost in transmission. As a matter of fact, this is not strictly correct; but if a station were operated at Chestnut Hill, it would be run at a bus bar pressure a little above the battery pressure, and therefore, for our present purposes, the assumption is correct. From our experience in operating power houses of various capacities, we find that a power house, operated at Chestnut Hill, under conditions which I have described, would cost about 1½ cents per K. W. hour output. We therefore get the following as the cost of generating the number of K. W. hours required by the Chestnut Hill branch during the month of October, if furnished by a station at Chestnut Hill:

134,848,919 K. W. hours, at 1½ cents	$2,022 73
Interest on $85,000, at 5 per cent. per annum	354 17
Depreciation on machinery, etc., at 5 per cent. per annum	354 17
Insurance, taxes, etc.	200 00
Total cost of operation for the month by direct method	$2,931 07

Actual cost of operating the battery and booster:

Watt-hours delivered to cable No. 3 by bus bar	136,576,919
" " generated by booster	34,234,648
Total watt-hours delivered to cable No. 3	170,811,567

We find the cost of operating the Beach and Green Street power house for the month of October, exclusive of interest and depreciation, was 7 mills per K. W. hour; therefore, we obtain the following:

170,811,567 K. W. hours, at 0.7 cents	$1,195 68
Cost of labor and supplies at battery house	179 73
Total	$1,375 41
Depreciation of battery at 5 per cent. per annum	83 33
Interest at 5 per cent. per annum on $33,000	137 50
Taxes, insurance, etc	32 00
Total cost of operation	$1,628 24

Deducting this from the cost of operating by a station at Chestnut Hill, we find the difference in favor of the battery for the month would be $1,302.83. At this rate the saving for the year is $15,633.96.

Recapitulation.

Saving in cost of intalling battery over a new power station for Chestnut Hill	$52,000 00
Saving in operation per annum	15,633 96

These results speak for themselves, and need no further comment. The following data may also be of interest:

Highest charge for 24 hours	456,000 watt-hours.
Lowest " " " "	312,000 " "
Average " " " "	385,161 " "
Highest discharge for 24 hours	456,000 " "
Lowest " " " "	216,000 " "
Average " " " "	329,419 " "
Average efficiency for the month, 85.5 per cent.	
Average day charge in amperes	46
" night " " "	155
" discharge " "	50

Ratio of the night charge to the day charge: highest, 1½ to 1; lowest, 4 to 1; average, 2.63 to 1

Ratio of day charge to discharge: highest, 1 to 4.45; lowest, 1 to 1.86; average, 1 to 2.95

Specific Gravity.

Maximum specific gravity at 6 A.M.	1.210
Minimum " " " 6 A.M.	1.2
Average " " " 6 A.M.	1.207

These are the specific gravities at the end of full charge:

Maximum specific gravity at 6 P.M.	1.201
Minimum " " " 6 P.M.	1.184
Average " " " 6 P.M.	1.192
Maximum specific gravity at 12 P.M.	1.194
Minimum " " " 12 P.M.	1.182
Average " " " 12 P.M.	1.188

Monday, 6th.

FIG. 7.—LOAD DIAGRAM AT STATION.

This last specific gravity is practically that immediately preceding the night charge, and is an indication of the amount taken out of the battery during the day. At a specific gravity of

DISCUSSION.

Mr. Carl Hering.—When was the test made, which was described in the first part of the paper?

Mr. Hewitt.—It was during a week in December, 1892.

Mr. W. C. L. Eglin.—Has it been decided when it would be more economical to replace the battery station with a generating station, and what would be the maximum economical output from a battery station, under the conditions at Chestnut Hill?

Mr. Hewitt.—It is rather difficult to give a general answer to this question. Each installation, of the character referred to, would have its own limitations. Theoretically, it would pay to put in a generating station, when the extra cost per unit, due to the booster, would equal the difference in cost per unit between the cost per unit at the larger station and the cost per unit at the smaller station. In the particular case under discussion, it would probably pay to put in a generating station at Chestnut Hill when the load on that section reaches the capacity of the present cables. In reply to the latter part of the question, I would say, that the less work the battery does, the higher will be the efficiency. In other words, the battery should be used simply as a potential regulator. The maximum permissible output, in the case under discussion, is 500 amperes, but the maximum economical output is zero output.

Mr. Scott.—This is a subject which has interested me for several years, and in two of the installations referred to, the Eckington and Soldiers' Home, at Washington, and the one at Dubuque, I was quite familiar with the facts. I am surprised at some of the results he seems to have reached. The figures he has presented as to the cost of accumulator traction in Europe and in this country are very different from my own. Take, for instance, the Eckington and Soldiers' Home line. The battery company by a separate contract guaranteed to operate the line at 12 cents per car mile, which was certainly evidence of confidence of their ability to do so. As a matter of fact it cost considerably less than 12 cents, and the battery company made money out of it in the year in which it was under their charge. I cannot recall the exact cost, but to the best of my recollection it was less than

10 cents, which compares quite favorably with the trolley traction at the present time, which Mr. Hewitt gives at 9.24 cents. When I say that the accumulator traction on this road in Washington cost less than 12 cents, I mean that it included maintenance, steam-power, management, help and everything that could be chargeable to the cost of running the road by batteries. The positive plates in that installation had an average life of five months. Mr. Hewitt gave the usual average as three months, which I think, taking the country through, is probably correct. In the Duluth installation the average was about four months. In that case the operation of the road was in the hands of the railroad company, supervised, but not controlled in any way, by a representative of the battery company. I think it is probably agreed at the present time that there are disadvantages in the use of accumulators on the cars, but in the matter of cost it is not quite so serious a matter as represented.

Mr. Hewitt.—In reply I would say that the figures I have quoted are the very latest that have been published. They are taken from two papers published during October of this year, in London *Engineering*. Of course I do not vouch for them. Some figures which I took from my own tests seem to corroborate them.

Mr. Scott.—In the battery which Mr. Hewitt tested, the diagram shows a very slight contact of the active material with the lead grit, which I regard as a very serious defect and one which would make a very great variation in the voltage. The narrowing in toward the end of the plug also lessens the amount of surface exposed to the electrolyte.

Mr. Hewitt.—I am not upholding this battery, but it seems to me it is quite foreign to the discussion what particular form of battery was used. This may not be a good form, and I don't doubt it is a poor form; but I wanted to bring out the fact that the general result, *i. e.*, the output of power per car ride, agrees very closely with the data which was collected from other sources. The total results compare closely with ours, and they are the chief thing. As Mr. Scott has brought up the Eckington and Soldiers' Home line, I would say that I visited that road myself while it was in operation with storage battery, at a time when

they were having trouble. Whenever a light snow came, the battery was rendered useless. It would discharge itself trying to overcome the snow, and the car came to a standstill. It is a very serious objection to all forms of storage cars, there being no reserve power for any snow storm, not even a light one.

MR. SCOTT.—But during the time the company operated the line in Washington, it was the only line that ran when snow was on the tracks. Of course, if the battery plates were worn out and were not renewed, they had no capacity to do any work. The conclusions he has drawn are based upon a very poor form of storage battery which he tested, and if he starts with such data he can hardly expect the results to be favorable to storage batteries. With six cars running at Dubuque, and with 5 per cent. grades, it required 1.1 electrical horse-power hour per car mile. In a two-weeks' test at Washington it required about eight-tenths of an electrical horse-power hour per car mile, both measured at the terminals of the dynamo charging the batteries.

XVI.

TOPICAL DISCUSSION.—SOME OPEN QUESTIONS CONCERNING STRUCTURAL STEEL.

December 19, 1896.

Note.—In the authors' revision of some of these papers, a number of changes and additions were made.

1.—GENERAL SUGGESTIONS ON SPECIFICATIONS FOR STRUCTURAL STEEL.

By H. H. Campbell, Visitor.

I understand I have been allowed fifteen to twenty minutes to talk to you on this subject, on which I have been working for something like fifteen years. This is a little different from my experience in the last political campaign, when I was told I must talk at least an hour on a subject I did not know anything about.

The greatest question in the manufacture of steel is the amount of phosphorus that is allowable. We say that the influ-

ence of phosphorus is mysterious and that its action is treacherous, by which we mean that the laws governing its action have not been formulated. Until they have been, the only safe way is to limit the allowable content; some engineers give .10 per cent. as a maximum (which will do very well for ordinary material); some, .08, some, .06, some, .04. Whenever there is a low limit to the phosphorus, you will find that the manufacturer will make that steel by the basic process. Some of you have a prejudice against the basic open-hearth, and therefore you will perhaps write in your specifications that the steel shall be made by the acid open-hearth process. You receive two bids, one high, the other low. You take the low, of course. Three months afterward you find that you are getting basic open-hearth. You object, but the manufacturer answers that the clause did not mean anything. What are you going to do? He will not make the steel by the acid process because perhaps he has no acid furnaces. You cannot sue him for breach of contract, because you cannot prove it is inferior material; and so you swallow the basic steel. The slightest consideration will show that you have not dealt fairly with the manufacturer who bid a higher price on low-phosphorus acid steel. This matter is an important question, and it is very desirable that engineers place nothing in the specifications they do not intend to carry out.

It is proposed by some engineers that phosphorus be guarded against by impact tests. I claim that these are entirely unnecessary in the majority of cases. They may do in axles; but in angles and beams and so on, it merely means the destruction of a great deal of good material and a great deal of delay, because you cannot make such tests until the shapes are all rolled. Moreover, they are of little value. You can find out whether the material is good by analyzing it. Unless the steel is burned you will usually have no trouble with the impact test, and you cannot discover over-heating by making one such test; one end of the bar may be burned and the other end be all right, or one small bar may be burned and all the other bars be in good condition. You must trust in great measure to the manufacturer. Moreover, if the bar is burned you can discover the fact by the tensile test just as well as by an impact test; and as for phosphorus, analyze for it, don't make an impact test.

There is a tendency in many specifications to limit the amount of sulphur. There are some people who disagree with me, but I do not think that sulphur ought to be specified on anything except rivets and eye-bars, and, of course, on flange steel for boilers. On other work I do not see what the engineer has to do with sulphur. You never heat an angle outside of the shops. A railroad bridge is not supposed to go through a conflagration and then be bent up and cracked. Rivets have to be heated after they leave the steel works and, therefore, it is necessary to guard against red-shortness; but if the manufacturer can work his steel into angles and beams or shapes, and can get them into a perfect section, I do not see what right the engineer has to throw out a hundred tons of bars, angles or beams, just because they run .001 or .01 per cent. above an arbitrary limit.

You write your specifications say 60,000 to 68,000, when, by the way, you should always give 10,000 pounds leeway and say 60,000 to 70,000; and then you say 38,000 elastic limit; 25 per cent. elongation; 50 per cent. contraction of area. This is all wrong. If 38,000 pounds elastic limit is right for the 60,000 steel, it is wrong for the 68,000; and if it is right for the 68,000, it is impossible for the 60,000. It is simply a law of nature that the elastic limit is proportional to the ultimate strength, and you cannot get away from it. You ought to make the elastic limit a percentage of the ultimate strength. The elongation will depend somewhat on the section; the contraction of area depends still more upon the shape and size of the piece. In a 3″ x 3″ angle you may get 50 to 60 per cent. contraction of area, while a 6″ x 6″ angle rolled from the same ingot will give only 40 to 45 per cent. contraction of area. It is the very same steel exactly, made out of the very same bloom, if you like, and yet it will not give the contraction of area. It is not the fault of the steel, it is the fault of the section of the piece. Take the same heat, the same ingot, and roll one bloom into a 6″ x 8″ angle an inch thick, and one bloom into a 3″ x 3″ angle one quarter inch thick, and the heavier bar will be two, three or four thousand pounds lower in ultimate strength. The two are exactly the same steel and yet an engineer will often accept one and reject the other. I have always fought for a sliding scale for all shapes.

A variation in the section produces a variation in the ultimate strength, the elastic limit, the elongation, and particularly in the contraction of area; and specifications ought to take that into account, particularly on forgings. Take a specification such as I mentioned; if it is a proper specification for angles and eye-bars, how can it apply to forgings? A piece cut from a forging will not give as good an elongation nor contraction of area. We had one specification calling for a piece cut out of the central core of a pin, and requiring that this piece should show as much contraction of area as a 3″ x 3″ angle. This is absurd.

We have a specification on our books now, requiring that, in the annealed eye-bar, the tensile strength shall not vary from the unannealed bar more than a few thousand pounds. The engineer did not know that he was insisting on bad material. The purer the steel, the more carbon it must have; and the more carbon it has, the more sensitive it will be to annealing or other heat treatment; and, therefore, the purer the material, the more it will fall off in the annealing, other things being equal. Of course, if a bar were finished too cold, it would be influenced by annealing more than it ought to be, but the danger from this source may be neglected, since the annealing will remove all injury that a bar will receive from cold rolling in any ordinary rolling mill.

Another point is the amount of segregation that is allowable. This segregation is an ever-present factor, sometimes greater than it ought to be; we don't like to have it at all, but it is and always will be present to some extent. You specify that your steel shall be .08 phosphorus, but you do not say how that test is to be taken; but we suppose, and there is generally no misunderstanding, that the test is to be taken in the usual way, according to the general practice of the country; but once in a while we run against an inspector who wants to take it another way. That is wrong. When you buy a roast of meat, you buy bone and meat. You don't expect to get meat alone and take off the weight of the bone; so when you get a bar of steel, you can find a part that is segregated. We want these facts to be known. As soon as everybody knows just how bad it is and just how good it is, so much the better. The top should be cut off; but all down through the center you will find a little segregation, and I claim there ought

to be an allowance of 25 to 33 per cent. allowed for the maximum content of phosphorus or sulphur. Mr. Cunningham allows that in his specifications. He is the only expert inspector who has come out publicly in favor of such an arrangement; and he knows that this is the proper thing to do while insisting on good material. If you want .08 in the most segregated portion, then specify .06 for the average. I believe that inspectors in general think that manufacturers ought to have a little more leeway. These inspectors understand their business; they know just about what is wanted; what the engineer wants; what the steel-maker can do. They understand the variations caused by variations in section and shape, but they have no power to exercise their own judgment at all. The engineer gives them a certain schedule and expects them to carry it out. He might just as well hire a clerk for a dollar a day if the sole requirement is that he shall carry out a complete set of specifications. With a little more leeway given to common sense and knowledge, the engineer will get just as good material.

2.—THE FAILURE OF STEEL MORE OFTEN DUE TO FAULTY MECHANICAL TREATMENT THAN TO THE PRESENCE OF RARE ELEMENTS.

By Albert Ladd Colby, Visitor.

The title announced by your Programme for Topical Discussion this evening is "Some Open Questions Concerning Structural Steel." The subdivision of this comprehensive subject to which I am assigned, is "The Influence of Various Agencies in the Course of Manufacture," and I ask your kind attention to what may be considered a negative side of this question, viz., The lack of influence exerted by certain constituents of steel not included in the usual analysis.

The careful investigation of the complaints made by the users of steel of a wide range of carbon manufactured by the company with which I am connected, constitutes part of the duties of my position. In this work my instructions are not those given to the Adjuster of a Life Insurance Company, to avail himself of the slightest chance, fair or foul, to shirk responsibility; on the con-

trary, the desire is to determine if possible the true cause of the trouble, a policy which sometimes entails an expenditure greater than warranted, so that in asking your attention to some of the conclusions drawn from an experience gained by these investigations, I beg you not to conclude that the object of my criticism of others' opinion, is a desire to shield the manufacturer's products.

I am convinced that there is too great a tendency now prevalent among consulting engineers when called upon to give a reason for the failure of some particular piece of steel, and among customers, in taking that initial step towards asking for a reduction in price, namely, entering a complaint of the utter failure of the last lot shipped for the purpose intended,—to saddle the blame entirely on the presence of a minute quantity of some element not included in the list, carbon, manganese, phosphorus, sulphur, and silicon, ingredients which have become so familiar to us, that we quote them as glibly as the "red—orange—yellow—green—blue—indigo—violet" of the spectrum.

Assuming that for the purpose intended, the steel contains the proper percentages of the elements ordinarily determined, it is fair to put two questions to those who would attribute its failure to the presence of a small quantity of some element not included in the usual analysis, the answers to which usually detract from the value of their explanation of the cause of the failure.

(1) Did you try a steel similar in composition except still higher in copper, oxide of iron, arsenic, titanium, or what not, for the same purpose, and if so, did it fail?

And (2): What analytical method was used for the determination of these constituents, and did the chemist also make a blank determination by his method, on a steel free from the ingredient and obtain a negative result?

The error in judgment which the man, anxious to find the cause of the failure, falls into when assuming that it is probably due to the presence of a small percentage of an unusual element, and that therefore he will turn his case over to his chemist to obtain facts to support his theory, is even greater than the error in analysis unconsciously made by the poor chemist, if unfamiliar with the difficulties of the analytical method for the determination of the rare element.

The more probable cause of the failure of a piece of steel, than for instance the presence of .10 per cent. copper or .15 per cent. of "oxides and slag," is the improper mechanical treatment the steel has received during manufacture or by the customer, and proof of this can only be obtained by the examination of the micro-structure of the steel by some one capable of interpreting from what he sees, the treatment the steel has received; or by a careful inquiry into each step of the manufacture as well as the customer's manipulation of the steel, along the lines indicated by the following questions:

If the steel was a *forging*, answers to the following questions will show whether the cause of failure lies with the manufacturer or not. Was the ingot used large enough to secure the proper amount of work on the steel in forging? Was the forging-machinery powerful enough to properly perform this work? Were the proper conditions of temperature maintained during forging? Were the distortions due to the internal strains developed during forging subsequently removed by an annealing of the steel?

Or, if the manufacturer's product was *rolled steel*, were his ingots heated too suddenly or too hot, or ununiformly, or allowed to soak in the reheating furnace before rolling. Or were they finished at too high or too low a temperature. If not, it is probable that an investigation of the customer's methods of handling the steel along these same lines, will show a more likely cause of the failure than to assume that it was due to the presence of a minute quantity of a constituent not usually determined.

Or if the rolled product is a *plate*, which cracked immediately after short service in the place where it had been flanged, the vital question is, was any attempt made by the customer to anneal the steel during cooling after flanging and thus remove the local internal strains and break up the local change of crystalline structure due to the flanging.

I have now indicated that failures are more probably due to faulty mechanical treatment than to the presence of what is assumed to be an undue amount of some element not usually determined in steel. I now ask your attention to a few instances cited from personal experience of the danger of drawing conclusions from the percentages reported by the average chemist of these rarely determined elements.

COPPER.—The ordinary chemist, unfamiliar with the difficulties of its determination, does not report all the copper contained in steel, as it is difficult to precipitate by an electric current *all* the copper present in a solution, especially if the amount is relatively small. It can be done if care is taken to keep the strength of the current constant, but many chemists do not realize the necessity of measuring the current, and hence simply attach a few cells of a battery or a few incandescent lamps and think that the requirements have been met as long as the current is not so strong that the copper deposits in flakes on the weighed platinum vessel. The error of incomplete separation of the copper could be materially reduced by taking 10 grammes of sample for analysis; such a large weight, however, is seldom used by chemists for the determination of copper, and is recommended by only one text-book on methods for analysis of steel (Arnold's).

It is not, therefore, surprising that in check analysis on carefully mixed drillings of an iron containing .078 per cent. copper, one chemist should have reported .044 per cent., and another that it contained *no* copper at all. It follows that probably many steels giving satisfactory results and represented to be low in copper, actually contain from .050 per cent. to .1 per cent., and would furnish evidence against the opinions of those who consider these percentages deleterious.

There is ample evidence that steels containing much larger percentages of copper than would be affected materially by errors in analysis, have proved as satisfactory for a great variety of purposes as similar steels low in copper. Mr. Campbell, in his book* on steel, just published, states: "Hard and soft steels of our manufacture have found their way into all channels of trade, and although many failures have come, as they have everywhere, from high carbon, high manganese, or high phosphorus, there have been no cases where it has been necessary to invoke the aid of copper. This fact outranks and transcends in value any limited series of tests that might be given. In the same way there is no evidence that copper segregates, experience pointing rather to perfect uniformity."

* "Manufacture and Properties of Structural Steel," by H. H. Campbell, N. Y., 1896, page 275.

The experience of the company with which I am connected coincides with the above. The examples given in the following tables are some of those which came under my personal supervision. Each analysis represents a seven ton heat.

Table No. I gives examples of high and low copper steels which gave similar satisfactory results on rapid reduction.

Table II shows that high and low copper steels underwent an operation similar to flanging with equally satisfactory results.

Table III shows a run of heats, containing higher copper than usual in our Bessemer Steel. The carbons varying from .11 to .65 per cent. These heats were heated and rolled as usual without the loss of a single bloom or billet on account of red-shortness.

TABLE I.

Low and High Copper Bessemer Steel, drawn at a single heat from 4″ billets down to wire .04″ diameter, without the slightest indication of red-shortness.

Copper.	Sulphur.	Copper plus Sulphur.	Carbon.	Manganese.	Phosphorus.	Silicon.
.067	.047	.114	.080	.40	.080	.009
.096	.062	.158	.076	.53	.066	.010
.306	.110	.416	.080	.32	.067	.010

TABLE II.

Low and High Copper Bessemer Steel, rolled into plates $\frac{1}{2}''$ to $1\frac{1}{8}''$ thick cut into disks, heated and forced into an octagonal armor plate cup in one operation, without cracking.

.055	.081	.135	.060	.31	.959	.010
.056	.108	.164	.068	.53	.065	.007
.061	.097	.178	.078	.57	.071	.008
.162	.115	.277	.068	.45	.076	.008
.251	.084	.335	.090	.48	.060	.005
.360	.087	.437	.064	.41	.047	.012

TABLE III.

Soft and Hard High Copper Bessemer Steel for Merchant Purposes, all of which was rolled without the rejection of a single billet on account of roughness.

.359	.072	.431	.126	.74	.074	.026
.355	.080	.435	.110	.91	.076	.022
.394	.098	.492	.110	.73	.079	.023
.292	.086	.378	.260	.96	.094	.080
.337	.105	.442	.300	1.12	.074	.116
.366	.092	.458	.480	.72	.072	.132
.486	.104	.600	.500	.67	.074	172
.373	.096	.468	.620	.73	.068	.316
.339	.087	.426	.640	.73	.076	.375
.380	.118	.498	.650	.75	.070	.298

Mr. Edward Riley* reports the results of 109 arsenic determinations in commercial steels used for a great variety of purposes which were collected without special selection to determine the amount of arsenic usually present in steel. The highest result found was .036 per cent. and the average only .005 per cent.

While the presence of small quantities of arsenic in steel cannot be taken advantage of as such by the customer as an explanation of the cause of failure, he can, however, and he does, do the manufacturer an injustice if he estimates the arsenic as phosphorus and rejects steel furnished to him under a strict phosphorus guarantee. A chemist analyzing a steel containing .01 per cent. arsenic without taking proper precautions for its separation in the determination of phosphorus, will obtain a result from .004 per cent. to .006 per cent. higher than the actual phosphorus present, depending upon the form in which he finally separates the phosphorus. This is an increment sufficient, especially in low phosphorus steels, to falsely represent the steel as over the phosphorus guarantee.

OXYGEN AND OXIDE OF IRON.—A marked contrast exists in the literature of the metallurgy of iron and steel, between the number of writers describing the effect of oxygen, and the number of actual determinations on which their statements are based. This is due to the fact that everyone knows that an excess of oxide of iron renders steel red-short and unfit for use, that the purpose of the manufacturer's final additions is to remove this objectionable ingredient, and as its accurate determination is such a tedious and difficult operation, it is easier for writers to draw conclusions from their knowledge of the manufacture of steel than to carefully determine whether the steel which failed for some particular purpose contained more oxide of iron than a similar steel giving satisfactory results.

Of the many methods which have been suggested for the determination of oxygen in iron and steel, Ledebur's is the only one which gives accurate results. It depends upon the ignition of the sample in a current of hydrogen and the absorption of the

* *Jour. Iron and Steel Inst.*, Vol. I, 1895, pp. 118–19.

Why are we using soft steel bridges to-day? Now, there are two reasons: first, because the supply of such material is abundant and cheap, and second, because of its flexibility it is easily manipulated and worked in manufacture in the shop. These are the real reasons why we are using that material and are the grounds on which I took occasion to urge its use before the Club some time ago. But ask engineers who are not in touch with steel making and metal working, why it is they prefer very soft steel, and nine times out of ten they will answer that they think it is just the stuff to stand impact because there is no danger of its snapping. Snapping is the word which is used, leaving one under the impression that it is a peculiarity of all other steel to snap. This opinion is erroneous on both counts. Soft steel is not the best material to resist impact, and if impact were great enough it would certainly snap. For when it comes to impact it is useless to pretend, for instance, that the conditions in a bridge stringer are anything like as severe as they are in rails with stresses which alternate under every wheel as it passes from tie to tie and subject to the direct shock of the loads; or to contend that the stresses in eye-bars are as severe as in engine-connecting rods in rapid motion and subjected to stresses alternating eight or ten times a second; or that any part of a bridge is subject to the shocks received by tires and axles. Yet for these uses, soft steel will not do. It is a failure. What is it which enables high carbon steel of very ordinary quality to do good service for years in rails and tires when soft steel fails? The reason is simply this, that the high initial rigidity of the material enables it to stand shock without deformation. Rails are enabled to perform the service which they do to-day because the elastic limit of the metal generally exceeds 50,000 pounds per square inch; and for no other reason. I know of no better way of enforcing this point than by quoting a recent writing of Mr. James E. Howard, who for years has been in charge of the Government Testing Laboratory at the Watertown Arsenal, Mass., and whose experience in testing metals is quite unequaled in this country, and probably by any one now living. Mr. Howard says: "It has been shown that rails originally very tough but of low elastic limit and tensile strength have lost materially in strength and become brittle

as the result of cold flow under wheel pressure. In other words, by reason of a low elastic limit the stresses imposed, caused readily a development of the elongation of the metal, and after that had taken place, fracture was effected, with reduced loading and without the display of appreciable permanent deflection. With rotating shafts it is shown to be unnecessary to overstrain the material beyond the limits barely showing a permanent set when observed with a micrometer, in order to eventually cause fracture. The mere possession of great toughness in the original metal does not signify that the metal will display any toughness before rupture; but, on the other hand, a succession of loads, no one of which causes distortion to the unaided senses, will ultimately end in rupture no less brittle than that of the hard steels. In steel of maximum tensile properties there is so little mobility of the parts that a lack of homogeneity, internal strains, or a concentrated stress, may cause sudden fracture." . . . "On the other hand, we are quite certain that the very soft grade of metal will be easily overstrained, and under repeated alternate stresses ultimately fail under precisely the same appearance of brittleness that the hardest metals fail; *i. e.*, in neither case will there be any display of toughness. Now the intermediate grades of steel will also do the same thing, but the advantage they have is this: they will endure a larger number of repetitions of stresses, and stresses of higher magnitudes than the softer grades."

Nothing could be clearer than this; nothing more damaging to the overestimate commonly placed on the value of softness or ductility. Fracture is due to overstrain and in metal of good quality can be caused by nothing else. This was the demonstration of Bauschinger's celebrated experiments since confirmed by Mr. Howard's own work at Watertown. It is singular that this great fact which metallurgists and mechanical engineers have not failed to note, has so generally escaped the attention of civil engineers.

It is a matter of interest to note also that these remarks of Mr. Howard's are called forth by the report of an investigation into the quality of steel required in the very latest type of structural material, the cold-drawn seamless tubing for bicycle frames. Lieutenant Eames of the Pope Tube Company of Hartford, Conn.,

as the result of careful investigation and many experiments declares that (with a possible exception of nickel steel) a pure steel containing .50 per cent. carbon is the only material which can be fully relied upon to meet this service.

Now, it must be admitted that a bicycle frame weighing only 7 or 8 pounds, which is not only capable of carrying a man of 200 pounds or more, but will remain rigid under his utmost muscular efforts and withstand the shocks of road riding, is an engineering evolution as notable in its way as a truss bridge. Hence these conclusions of Lieutenant Eames are interesting, especially as they have called forth the cordial endorsement, first of Mr. Howard, and later of Mr. John Fritz, the venerable engineer and Superintendent of the great plant at Bethlehem.

So far then as impact and snapping are concerned, it must be admitted that our fears are not well founded; are, indeed, unscientific, and the fact remains as stated above that we are using soft steel chiefly because of the advantages it offers in manufacture. This consideration will undoubtedly continue to give soft steel the chief place for efficiency and economy in structural work. But when it comes to requiring soft steels to be reamed or drilled in the solid, to the use of soft steel in bridge trusses of large span, to its use in pins, rollers and bed plates, I think it is time to raise a question as I have done to-night, and ask if economy, good shop practice and sound engineering would not be better served by the use of higher carbon steel.

4.—THE INFLUENCE AND EFFECT OF DYNAMIC STRESSES ON MATERIAL AND STRUCTURES.

By James Christie, M.E., Active Member of the Club.

The following brief review of the subject embraces several distinct considerations, which are offered as the results of experience.

First.—The forces that act on materials in use are to a large extent of a dynamic character.

Second.—When iron (including steel) is destroyed by stress of this kind it usually yields progressively, that is, the metal is injured or severed by degrees, or in detail.

Third.—There is a marked difference in the comparative endurance of different grades of metals, and the advantage does not remain with the very ductile metal of low tensile strength.

Fourth.—The usual method of testing by direct tension, does not furnish sufficient indication of the capacity for long endurance to dynamic stresses.

These tests should be supplemented by systems which either recognize the kinetic forces, which are rarely absent, or indirectly furnish evidence of the comparative resistances of different metals to destructive shock and vibration.

The influences exerted by kinetic forces as problems in mechanics, have been the subject of careful investigation, and have received ample attention at the hands of the eminent analysts who have honored science with their labors. But as problems in physics, the effects exerted on the material are not so well understood, especially the effects of compound or orthogonal stresses, or of percussion and vibration. There is much work for the physicist in this direction, which may reveal some hidden properties of the metal, or throw light on disputed points which are now obscure.

Physical tests of materials should simulate as nearly as practicable the forces which act on material in its daily use. It is a fact well known to those accustomed to the testing and use of steel, and indeed of iron in any form, that a comparatively feeble resistance to impact or shock may be exhibited by material whose resistance to ordinary static stress is satisfactory. Sometimes the source of the weakness is revealed by chemical analysis, but not always, possibly because the analysis may be incomplete, or we do not understand the complex influence exerted by the various combinations of the associated ingredients, or the molecular condition of the metal may be unsatisfactory, for other reasons imperfectly understood. A very common cause of fracture arises from the effect of impactive forces which act with great intensity at a particular locality, causing rupture in detail, or the material yields by degrees.

Forces of this character are especially destructive to some steels, while others resist the assault more effectively. The problem is to know what metal best survives the ordeal, and give it

the preference, or exclude the objectionable material. The question of the relative merits of steel and iron for resisting shock and vibration has been long disputed. The subject is occasionally revived, perhaps because imperfect steel is a more dangerous metal than imperfect iron. But when we reflect on the more severe service that steel is now required to endure than iron did a score of years ago, one can readily realize what a retrogression it would be were we required to return to more primitive methods.

The dynamic stresses to which steel is subjected, arise from loads applied impulsively, or in rapid repetition or alternation. The latter may cause vibrations which may be cumulative in character.

Impactive forces or percussion usually exist and frequently act at right angles to an existent static stress. Most insidious of all are forces of the latter character, especially when the percussion acts through a comparatively small mass at a comparatively high velocity, producing concentrated local stresses of high intensity, causing rupture by degrees or in detail, as exemplified in the head of a pile or a chisel, where the surface on which percussion first acts is destroyed, while the material beyond it is uninjured.

Again, material may be destroyed by reason of its inability to properly distribute a stress throughout a sufficient extent of its mass. For example, in a shaft with an enlarged diameter (if the junction is sharp or without a fillet), it has been shown that moderate stresses elsewhere may become infinite at the sharp junction. Even with an abundant fillet at such a junction the local stresses become considerably augmented, accounting for the facility with which shafts frequently break at these junctions. Or large screw bolts may break without perceptible stretch or diminution of cross-section, owing to sharp angles at the root of the thread, and the force applied to the nut not being transferred by the external material of the bolt to the material near the center.

It may be premised that if steel has its proper elastic quality, and if the forces acting on it are normal (that is, the stresses are equally distributed), no matter how suddenly they are applied.

the strains will also be normal; that is, the full measure of resilience will be exhibited by alteration of length and section. We may further assume that if the stresses are sufficiently below the elastic limit, they may be repeated *ad infinitum* without injury to the material. We assume the foregoing to be correct because there is no evidence that it is not, and yet we frequently witness the rupture of material that yields without apparent stretch or diminution of section, and where the total stresses, as near as can be ascertained, are well below the elastic limit of the total resistant section. An investigation of the causes generally indicates the existence of well-defined local stresses of high intensity, and an inability of the material to transfer these stresses throughout a sufficient portion of the material, the material is not sufficiently plastic (using plasticity in the opposite sense to brittleness), and yet this material may exhibit good physical qualities when exposed to the ordinary pull of the testing machine.

That progressive rupture is a common occurrence is demonstrated by the fact that quite frequently evidences of approaching rupture are discovered in advance, or when final rupture occurs, the existence of partial rupture at a previous period is presented. Material thus destroyed parts without sensible change of shape, and, in the case of wrought iron, the ruptured section usually, if not always, presents a granular surface. This appearance probably accounts for a widely prevalent belief that wrought iron, originally of a fibrous texture, becomes granular or crystalline through the effects of shock or fatigue. It does not follow that a clean, bright fractured section indicates that the destructive force was distributed in a normal manner, for the rupture may have been rapidly progressive; akin to a tearing process.

It is to be observed that fractures of the foregoing kind most frequently occur in material subjected to direct shock, combined with transverse or bending stresses, as in rails and axles. In instances such as rods of stamps and hammers, the life is limited, being longer or shorter, according to the resistance of the material; but failure within a definite period is expected, and occasions little surprise after a reasonable survival. Fortunately, the members of bridges rarely break in this manner, partly because the ties act as a cushion, relieving or distributing the impact, but

principally because the members can be so disposed that the forces are better and more evenly distributed than is practicable in some other cases.

It has been demonstrated from the fundamental principles of mechanics that the effect of a load instantaneously applied is double that of the static effect of the same load; or, the total stress is the sum of the gravity and inertia stresses. This has long been recognized in assigning to a live load some arbitrary values in excess of its static effect. It rarely, if ever, occurs in practice that a load is applied instantaneously without impact; but in the case of rapidly moving loads there is some approach towards such action. Nearly fifty years ago a Railway Commission in England observed that certain bridges deflected about 15 per cent. more by a train passing at fifty miles per hour than they deflected with the same train at rest. Fairbairn subsequently made his experiments on girders subjected to vibration caused by repeated applications of a load, all of which are on record. The roar of a rapidly moving train conveys sufficient evidence that impactive forces are also at work; and the not infrequent destruction of wheels, axles and rails, which are the first to receive the shock, indicates that experience alone can enable us to form any correct estimate of the forces to be considered. In a paper to the American Society of Civil Engineers, Mr. S. W. Robinson describes a series of experiments with a recording indicator which registered the vibrations of the structure under passing trains. According to his record, the additional stress due to vibrations or oscillations caused by non-balanced parts of the locomotive, was 28 per cent. of the greatest stress caused by static action of the train. Also, another additional stress due to vibration from, or impact of, the body of the train, was 50 per cent. of the stress due to the corresponding part of the train statically considered.

The extensive and valuable experiments of Wöhler and Spangenberg proved the existence of the fatigue of metals, or that rupture would occur under a variation or alternation of stresses, the greatest of which was less than the ordinary ultimate resistance. Based on these experiments, formulas have been propounded by Launhardt, with numerous modifications by others, for application to bridges and kindred structures. The system

has been objected to, inasmuch as the fatigue referred to occurs at stresses above the elastic limit, whereas no structure should allow the total sum of stresses to reach this limit. Another system is to allow for the effects of impact and vibration, by assigning a variable quantity dependent upon the length of loaded distance, and add this to the live load.

In a paper before the Royal Society, Sir William Thomson [Lord Kelvin] recounts certain experiments made at the University of Glasgow in 1865, which appear to establish the existence of a fatigue of elasticity in materials, a subject entirely different from the fatigue of strength observed in the German experiments. This was exemplified by a loss of energy in elastic bodies after they had been kept in vibration for a period of time; or, the subsidence of vibration was more rapid after prolonged vibration than occurred when the vibrations were started from a prolonged state of rest. This would indicate that the molecular friction (or viscosity of metals, as Thomson called it), which we must assume to be the passive agent or resistance to elastic action, is augmented by prolonged vibration. I believe a period of rest restored the normal elasticity.

This phenomena might have some bearing on the endurance of metals subjected to constant percussion and vibration; and it would be an interesting question to learn to what extent, if any, it might depend on the composition or quality of steel. Unfortunately, experiments of this character require considerable time and patience for any exact determination, and they are not susceptible of application to the practical demands of daily life.

A few years ago, when steel became extensively used, there arose a general disinclination to trust the harder grades (that is, iron associated with any considerable percentage of carbon), and to give preference to those grades in which the proportion of carbon was approaching the vanishing point, as a substitute for wrought iron. It was soon discovered that the trouble with the higher grades was usually attributable to imperfect or non-uniform composition; that is, objectionable material was excessive either uniformly throughout or concentrated in localities. When these evils were corrected, the other trouble was much abated, and the higher grades of steel were found to offer a greater

resistance to shock than the very soft and ductile metal. This was clearly the case in metal for ordnance and armor, where the greatest possible strength, conjoined with a high range of viscosity and greatest resistance to erosion was essential. For hammer rods and similar cases, exposed to destructive shock, the superiority of the stronger metal seems to be established. The leading railroads, after an extended experience with soft steel in axles, have now turned to harder metal, and the term axle steel is now frequently applied to metal containing about $\frac{4}{10}$th per cent. carbon and low in the other components.

An instructive experiment was recorded a few years ago by Metcalf, of Pittsburgh, in which the superior resistance of the higher grades of steel to shock and rapid vibration was observed. Small connecting rods running 1,200 R. P. M. were operated until they broke. A number of specimens varying from .30 to .90 carbon were tested, showing marked longevity for the higher grades.

A series of valuable experiments was made by Baker ten years ago, in connection with work at the Forth bridge, on iron, also steel of 60,000 pounds tensile strength and steel of 120,000 pounds tensile strength. These were rapidly repeated and rapidly alternated bending stresses, and indicated superior endurance for the hard steel—equal sections or equal stresses considered—although the soft steel longer endured a working stress more nearly approaching its nominal elastic limit than the hard steel did. These results also indicated that stresses of the character described, apparently below the elastic limit, finally resulted in rupture. The rupture also was usually progressive; that is, incipient fracture occurred, sometimes considerably in advance of ultimate failure. It would have been interesting to know how a grade of steel would behave midway between the extreme grades tested, or what would have been the result if impactive forces had been added.

But aside from the question of the most desirable grade of metal to use to resist shock, arises the subject of the subsequent treatment of the metal, presuming that the composition is perfect. This involves a tedious discussion, with which I cannot tax your time and patience at present, except to paraphrase the

old motto: "Unceasing vigilance is the price of success." We do know that some steel endures an astonishing amount of severe treatment, as compared to another steel, differing from the other metal in no marked degree. Whether these differing physical qualities are more the effect of the mode of manufacture, or the composition, or the subsequent treatment, is a debatable question. It is probable that the nearer we get to pure iron associated with carbon only, the better the steel; and for the most usual applications of the metal in structures and machines, and I would even venture to add ships hulls' and boilers, we might anticipate the best results from a carbon content, as high as now used in ordnance or armor.

When discussing Mr. Hunt's paper, in 1893, on a new method for testing structural steel, the writer suggested: "If the upper shank of a punching tool was formed into a tapering drift and a segmental die used which would open laterally when penetrated by the drift, the operator could measure the resistance to, or work done by, punching and also that due to the distention of the specimen by the drift." It is quite probable that if specimens were sheared to definite dimensions, and offered a definite resistance to punching and drifting, and the punched holes distended a definite amount before cracking, we would have as useful a criterion as could be devised for judging the quality of structural steel.

5.—NOTES ON THE PRACTICABILITY OF USING HIGH CARBON STEELS FOR FORGINGS.

By Albert Ladd Colby, Visitor.

In your Topical Discussion this evening under the sub-heading, "The Practicability of Using the Higher Carbon Steels," I have been asked by several of your members to give some examples drawn from the experience of the Bethlehem Iron Company of the practicability of using high carbon steels for forgings. These examples will serve as illustrations of the success obtained in carrying out the principles which Mr. Christie has so clearly and ably presented in his paper to which we have listened this evening.

It is only in recent years that high carbon steel has been found available for this class of work. Frederick Krupp, of Essen, was the leader in substituting his soft crucible steel for wrought iron in heavy forgings. After 1870 soft open hearth steel became a more frequent substitute with such success that, compared with wrought iron, the soft steel forgings made by such firms as Vickers Sons & Co. of Sheffield, and Sir Joseph Whitworth & Co. of Manchester, England, soon attained a high reputation for their quality.

SHAFTING.—It was therefore natural that our Government officials, when first issuing specifications for the heavy engine and shafting forgings required for the rebuilding of our navy, followed in the line of the English practice and called for a steel, having a tensile strength in the specimen cut from the forgings, of 28 to 30 tons (62,720–67,200 pounds) per square inch, and a minimum elongation of from 22 to 28 per cent., according to the dimensions of the specimen and the severity of the specifications. To-day, however, we are called upon by the Government to furnish a steel for thrust, line and propellor shafts, which will show a tensile strength of 80,000 pounds (36 tons), an elastic limit of 50,000 pounds (22 tons) and an average elongation of 25 per cent. in 4 diameters, and the International Navigation Company also specifies for shafting a steel of an elastic limit of 50,000 pounds and 25 per cent. elongation in 4 diameters. These requirements are met by using a steel of 30 carbon and 3¼ per cent. nickel.

CRANK-PINS.—The character of steel now used by some railroads for crank-pins furnishes a marked illustration of the practicability of using high carbon steels. When steel was first used in such pins in place of wrought iron, a soft low carbon steel was generally employed, and the failures due to "fatigue" of the metal were almost as numerous as when wrought iron was used. The broken pins showed what has been called "a fracture in detail," a gradual parting of the steel extending inward all around the piece, undoubtedly produced by the working strains repeatedly approaching the low elastic limit of the soft steel. On substituting a steel with an elastic limit of 45,000 pounds, failures were greatly diminished, and that, without changing the diameter or shape of the pin. We make crank-pins of fluid compressed

open hearth steel of about the following composition, which have given excellent satisfaction in locomotive service:

Carbon	.40—.45
Manganese	.60—.70
Phosphorus and sulphur	.030
Silicon	.10—.18

This same grade of steel is now being used by such firms as the Southwark Foundry and Machine Company, Philadelphia; the Corliss Steam Engine Company, Providence; the Atlantic Works, East Boston; Frazer & Chalmers, Chicago; for piston and connecting rods and crank-pins, under specifications of 40,000 to 45,000 pounds elastic limit, and 18 to 20 per cent. elongation.

HAMMER RODS.—The use of soft steel for piston rods for steam hammers, especially for those of large sizes, is a good example of the error into which engineers have been led by the exercise of a caution which was not based on a thorough knowledge of the facts. The argument that the soft steel was safer because less liable to rupture if subjected by accident to a sudden transverse blow, has caused engineers to select so soft a steel that it was unable to resist for any length of time the strains put on it in regular service, strains which so constantly closely approach the low elastic limit of soft steel that the metal breaks down from gradual fatigue, causing distortion, which is soon followed by fracture.

Some years ago, we persuaded a customer to allow us to use a 45 carbon steel for a hammer rod. This rod was 19′ long, the lower half 18″ diameter, and the upper half 10″. The machined weight was 6 tons. We used a fluid-compressed ingot containing: carbon, .45; manganese, .48; phosphorus, .025; sulphur, .030; silicon, .144. This rod stood very severe service for three years and seven months, which was so much longer a period than the soft steel hammer rods previously used had lasted, that our customer, in ordering one to replace it, asked us to make the carbon still higher. We have, therefore, furnished a rod which is now in use, selecting a steel analyzing: carbon, .55; manganese, .74; phosphorus, .024; sulphur, .030; silicon, .181; and obtained the following results on a 2″ test-bar, machined cold, from a prolongation of

the forging after finished annealing; tensile strength, 103,390; elastic limit, 53,980; elongation, 17.10; contraction, 28.76.

A similar example of the success attending the substitution of a higher carbon steel is found in the record of a ram for a 20-ton hammer, where excellent service has been obtained from a 43 carbon steel. The test-piece from the finished annealed forging gave the following results: tensile strength, 87,440; elastic limit, 48,060; elongation, 15.00; contraction, 63.84.

In the cases just cited, the forgings were simply annealed after forging. The following record shows the advantages gained by oil-tempering high carbon forgings. We furnished a piston rod for a 20-ton hammer made of 45 carbon steel, which has now been in use five years, nine months. The rod is 19′ 4″ long and 12″ diameter, and has a 4″ axial hole bored after forging. After forging and boring, it was annealed, oil-tempered and reannealed, and a test-bar taken from a prolongation of the forging after final treatment gave the following results: tensile strength, 88,970; elastic limit, 50,100; elongation, 22.85 per cent.; contraction, 47.07. The analysis of this steel is: carbon, .46; manganese, .63; phosphorus, .021; sulphur, .026; silicon, .155.

Selection of Steel for Forgings.—No fixed rules can be framed in the selection of steel for forgings, as the size and shape of the piece and the qualities most desirable for the work it is intended to do, make each case almost a separate study. In general, however, it can be stated that our experience shows us that where high duty is demanded from a forging, mild steel of a tensile strength of 60,000 pounds (28 tons) is not the best material to use, owing to its low elastic limit. In substituting hard or higher carbon steel we recommend that the forging should be oil-tempered whenever practicable, as this treatment effects a decided improvement in the physical qualities, increasing both elastic limit and toughness. The less the sectional thickness of the piece the more its qualities are improved by tempering. In order to successfully temper a large forging, especially if cylindrical in shape, it is necessary to provide it with an axial hole throughout its length. In cases where oil-tempering is not practicable and special requirements are demanded, they can be obtained by using a somewhat softer and tougher steel and the introduction of from 3 to 4 per cent. nickel. This nickel increases

the ratio between the elastic limit and tensile strength and also adds to the ductility of the steel. The following statement shows the average physical qualities that can be obtained in forgings made of the several grades of steel mentioned; the test specimens being ½ inch diameter and 2 inches long between marks and cut from full sized prolongations of the forgings after treatment; the elastic limit being determined, not by the drop of the beam, but by an electric micrometer.

	Mild Steel Annealed.	Medium Hard Steel Annealed.	Medium Hard Steel. Oil Tempered. (Axial hole where practicable.)	Medium Hard Nickel Steel Annealed.	Medium Hard Nickel Steel, Oil Tempered. (Axial hole where practicable.)
Tensile strength	63,000	80,000	90,000	85,000	93,000
Elastic limit	30,000	37,500	48,000	50,000	60,000
Elongation	28 p. c.	23 p. c.	23 p. c.	25 p. c.	25 p. c.
Contraction of area	50 p. c.	40 p. c.	50 p. c.	50 p. c.	60 p. c.

In naming the above qualities in tempered material, the sectional thickness is assumed to be considerable, say 3″ and above; when the thickness is reduced to say 1″ to 1½″, the elastic limit of simple steel can be raised to about 55,000 to 60,000 pounds, and of nickel steel to 65,000 or 70,000 per square inch, without reducing the ductility.

This table will be included in an article on Marine and Engine Forgings, written by our Vice-President, Mr. R. W. Davenport, which will appear in the Marine Number of *Cassier's Magazine*, to be issued early in 1897. Mr. Davenport also treated this same subject in a paper read in 1893 before the Society of Naval Architects and Marine Engineers, entitled "Production in the United States of Heavy Steel Engine, Gun and Armor Plate Forgings."* The subject of Hollow Forgings has been well covered in a paper read last May at the St. Louis meeting of the American Society of Mechanical Engineers by H. F. J. Porter.†

* Transactions Society of Naval Architects and Marine Engineers, Volume I, 1893, page 70–90.

† Transactions American Society of Mechanical Engineers, Volume 17, pages 359–371.

NOTE.—At the close of the meeting, Mr. Colby exhibited a book of large photographs of some of the high carbon steel forgings made by The Bethlehem Iron Company. In the description under each photograph was a statement of the excellent physical results obtained from test specimens cut from full-sized prolongations of the forgings after final treatment. Examples of a few of these are given in the following table:

DESCRIPTION.	Tensile Strength.	Elastic Limit.	Extension. (Per cent.)	Contraction. (Per cent.)
Mild Steel, Annealed.				
Intermediate Shaft, American Liner	72,615	36,050	30.00	54.55
Thrust Shaft, I. P. Morris	65,710	35,940	28.30	50.31
Medium Hard Steel, Oil Tempered.				
Cross-Heads, American Liner	89,095	45,320	24.65	53.20
Connecting Rod, Union Iron Works	90,500	51,130	23.00	57.56
Piston Rod, Union Iron Works	89,990	51,130	25.50	63.10
Medium Hard Nickel Steel, Oil Tempered.				
Line Shaft, Torpedo Boat	105,240	73,930	24.40	60.99

6.—A MIRROR APPARATUS FOR MINUTE MEASUREMENTS OF CHANGE OF LENGTH AND A POCKET RECORDER FOR STRESS-STRAIN DIAGRAMS.

By GUS. C. HENNING, Visitor.

THE first apparatus shown is very simple; two mirrors are attached to spindles carried by knife edges bearing against the test bar to be strained; scales are mounted at a given distance from the mirrors, and a telescope is placed at any convenient point for reading the scales reflected by the mirror.

Fig. 1 shows a top view of the frame with the mirrors removed; also a front and a side view of the anchors *G*. Fig. 2 shows the

general arrangement of the mirror and appurtenances about twice full size; also a separate side view of the roller or rocker knife edge, carrying the yoke *Y*, drawn full size. Like parts are marked with the same letters in the different views. Fig. 3 shows the instrument as applied to a cylindrical test piece.

The parts of the complete instrument which are not shown, are a telescope with a $1\frac{1}{2}$ m. or 5 feet focus as a minimum, and 10

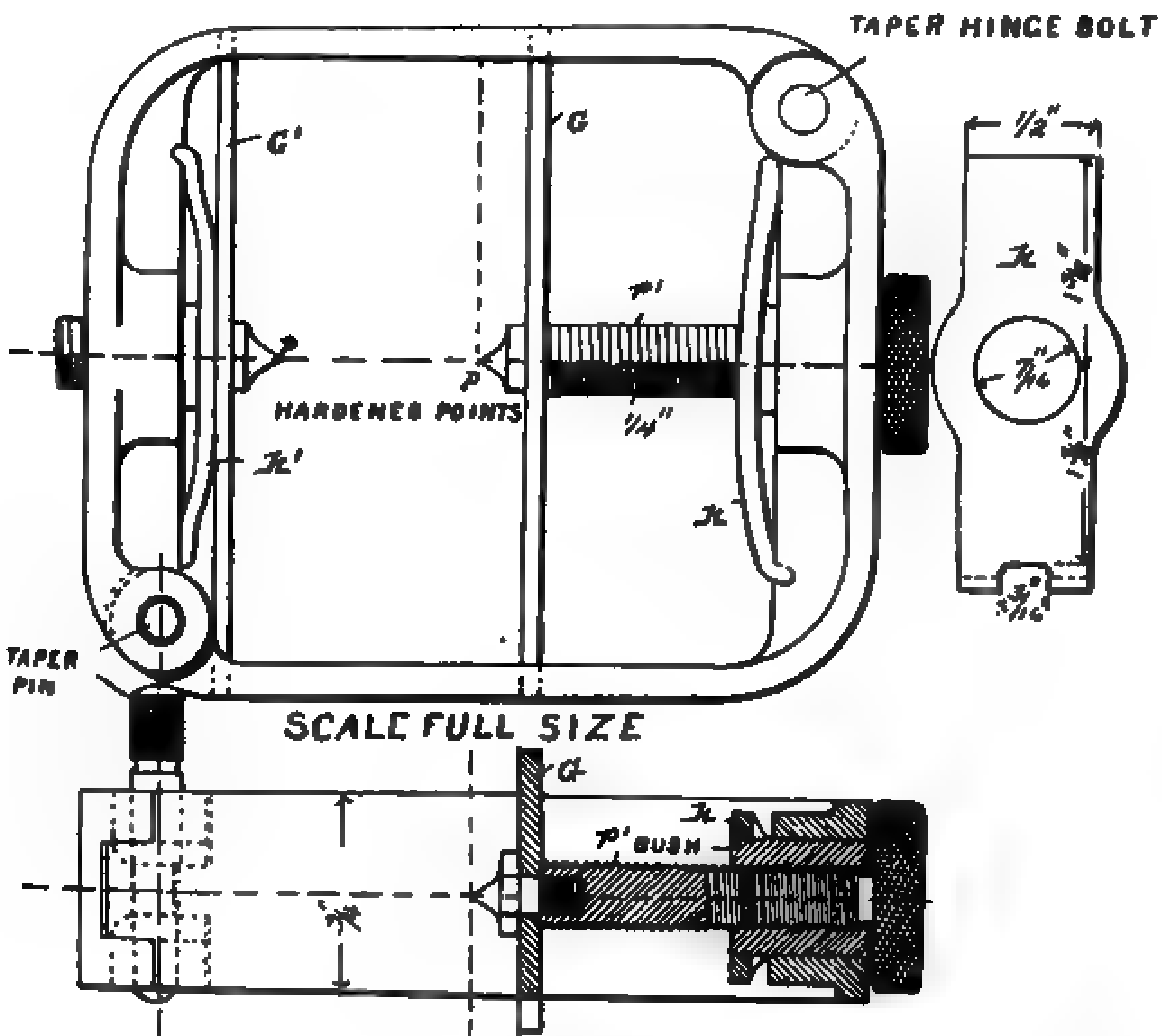


FIG. 1.—FRAME.

feet as a maximum; also a pair of double scales, U. S. and metric, divided into $\frac{1}{100}$ inch and m.m. side by side, with reversed figures, the scales being about 20 inches long and mounted side by side, one on each side of the object-glass of the telescope. The telescope is supported on a metal stand permitting of a motion about horizontal and vertical axes, and having three leveling screws. The

the construction of the latter, in three parts as shown; the spindle carrying the mirrors is screwed into the knife edges and when one edge lies in the cut (or groove) in *Y* the under side rests on a small adjusting screw *a*. The spindle of the mirror is screwed into the rocker so that a quarter turn can be given it by the fingers, to interchange the U. S. for the metric dimensions and still have the mirror in the original position. The spindle carrying the balance weight is screwed in firmly.

The upper edge of the spring *S* allows the rockers and mirrors to swivel, when the opposite sides of a test piece are not strictly parallel, without producing torsion in the springs *S*.

The small nut at the upper end of *S* does not bind the *Y* (yoke); this nut is removable, so that it can be taken off easily. The object of this is, that when using the instrument for measuring compression, the yoke *Y* can be turned upside down, which does not shift the distance between the axes of *D* and *P* when the whole instrument is attached upside down. When the test piece extends, the rockers will rise and bear only in the groove in the yoke and at the test piece. In compression the rockers revolve in the opposite direction, as clearance space is provided in that direction by reversing the yoke.

The screw *R* bears against the mirror which is held against it by a delicate leaf spring shown. The counterweight is very light, but just heavy enough to keep the mirror horizontal when supported in holes in yokes; the holes in yokes are larger than the spindle, so that it cannot touch at any point.

The bending of the springs *S* is such as to produce ample pressure on the knife edges, when the points p and p_1 bear against the test piece, so that the mirrors are carried positively by this pressure without further assistance, even under the effect of vibrations, like those in machine shops, so that when once applied the mirrors cannot slip when affected by tremors.

As the two mirrors are attached to opposite extreme elements of the test pieces, the average of the two mirror readings will be the true axial change of length under observation.

The principle on which the apparatus is based is that a ray of light reflected from a mirror describes an arc which is greater than the actual angular motion, in proportion to twice the length of the radius; that is,

$$\frac{2\,R}{r} = \frac{l}{d} \text{ or } l = \frac{2\,R.d}{r}$$

in which R and r are the large and small radius respectively, l the measured deflection, and d the distance moved through. Hence, if $r = .24$ inches and $R = 60$ inches, then, as the readings are taken from two mirrors, the sum of the readings will be

$$\frac{4\,R}{r}d = \frac{4 \times 6000}{24}d = 1000d$$

Now, all that is necessary to obtain great accuracy is to know r exactly, and as this is easily obtained by various measuring machines at any time, the instrument can be readily verified, and is not likely to change. There is probably no other instrument so simple and less subject to variation. This is the most accurate instrument made for the purpose of determining changes of length; and it is really intended for laboratory work, where alone such fine work can be done. In a mill, resort must be had to less sensitive instruments, because they are subject to all sorts of disturbances on account of vibrations and oscillations.

The elastic limit is determined by watching the passing of the scale in the glass, by the rate of changes. The weight on the beam is noted at the instant of the change of rate; this is the elastic limit. It is so delicate that you can only observe the beginning of the elastic limit; because at that instant the scale rushes by the glass and the readings can no longer bė taken. The ordinary way of determining the limit of elasticity is of course simply noting the change of length which suddenly increases at the elastic limit and increases very much more rapidly at the yield point. Some use the drop of the beam to indicate the elastic limit or the yield point; but as this is very inaccurate I always put a pair of dividers, with a glass mounted on one leg, so that I can use it up or down or any way; I can read off a hundredth of an inch with the greatest facility, and there is then no question whether the elastic limit has been reached. The old method of determining the elastic limit has practically gone out of use, because it is so easy to let the machine do it and take its indication for the accurate limit.

Since devising this instrument I have found it necessary to

study materials more carefully, and I am not at all satisfied that the tension tests are satisfactory unless more than the yield point, the tensile strength of the material and the reduction of shape and elongation are to be determined. In testing wire, which I had to do recently, I found I could determine nothing except the elongation at the instant of fracture and the tensile strength. The elastic limit was not observable, nor was the yield point, and in suspension bridges it is necessary to know the modulus to determine the deflection of cables. I had to use better means in order to determine the quality of the material. I took some cards from the instrument called a "pocket recorder" used for that purpose. I claim that without the observations of the elastic line and character of the material within the elastic limit, we know altogether too little about the material to say that that material is thus, or is not. It has always been my object to produce a little instrument which I can carry with me and put on any machine to get a diagram of the material under observation and thus have a permanent record regardless of what the machine is doing, or of what the man at the other end of the machine may be trying to do; I have taken a Tabor indicator as the handiest instrument and modified it to suit the purpose. The modification consists in cutting off the cylinder in the first place and providing it with two screws, having knife edges which are attached to the wire test piece. The instrument carries itself by these knife edges The upper end is attached in the same way. The indicator mechanism is attached by a little ball and socket joint, such as is used in the indicator. The indicator mechanism of course gives a straight line motion, and the one thing to be provided for is that the instrument is not broken at the time of rupture of the test piece.

The instrument itself, every time that the test piece breaks, separates into two parts, but not so as to hurt it. This instrument can be used as well for larger pieces as for small ones. The only difference in construction is that the frame is made suitable for a larger piece; but as I built this especially for wire it answered the purpose. It is not more delicate than any ordinary indicator; the shock at the instant of rupture does not hurt it at all; the levers are all spring steel and the connection is very

light, merely slipping into a nicely fitting hole. The mechanism works with so little resistance that it is practically frictionless; and the friction of the pencil on the paper will not disturb it, so that there is never any danger of one part slipping out of the other and giving incorrect diagrams; the upper part weighs only a few ounces.

With such an instrument, which can be attached to any testing machine, we can learn very much. It is started with the drum wound up, that is, a spring or weight revolves the drum, winding up the string. Now the string is taut, and the weight on the beam stands at zero. Another string leads to either proportional pulleys or a lever, connected to the poise weight; as the latter moves, the drum revolves. Under low loads, there is a full strain on the string. Just as soon as the weight is increased, the drum will run back; the strain becomes less; as the load on the beam becomes higher, the strain is almost entirely relieved. Using a weight, instead of the spring, gives more uniform results. This is a compact instrument for obtaining autographic records, and is, I think, the first of its kind. All other instruments can be used only on the machine for which they were designed. It does not make any difference what kind of running weight there is on it, you can always get the proper motion of the drum by the proportional pulleys or levers, which move with the weight across the beam. This recording instrument has never been shown to any one. You are the first to have seen it.

7.—GENERAL DISCUSSION.

By Mr. Kreuzpointner, Visitor.

It is perhaps rather presumptuous on my part to accept the kind invitation of your President and discuss, in the presence of so many eminent engineers and metallurgists, such an important subject as steel. However, I am very much interested in the subject and will make a few remarks on the papers read. I beg you, however, to consider my remarks as merely expressing my personal opinion and in no way representing the opinions of my superiors in the Pennsylvania Railroad Company. I shall be

glad to bring to your notice, in as few words as possible, some of the observations which I make daily on the behavior of steel.

The first speaker, Mr. Campbell, objects to impact tests on bridge steel. I am not a constructing engineer, and do not wish to be understood as if I desired to criticise Mr. Campbell's remarks; I merely call your attention to some experience I had only yesterday. An engine truck axle was received, which showed a fine crack all around the periphery of the journal. On putting the axle in the testing machine and applying a load of 100,000, no other effect was visible except the indentation made by the knife edge of the strut. I then had the axle taken to the smith shop to be broken under the steam hammer. The supports were three feet apart and with only one blow of the hammer-head of a three-ton steam hammer, from a height of only 6 inches, the axle broke through the crack like glass. You may draw your own conclusions regarding the relative values of a static load or steady, uniform pressure of 100,000 pounds, and the dynamic load or force of impact of a light blow of 6 inches height of a three-ton steam hammer, on the same structure, and whether it would be wise to abandon impact tests.

Mr. Campbell expresses good common sense when he thinks the engineer should prescribe the elastic limit in his specifications as a given percentage and not as so many pounds of ultimate strength. If Mr. Campbell had told you how to take the elastic limit so that we really know what we have, he would have done you a still greater service. If the engineer prescribes 35,000 elastic limit, as Mr. Campbell says, to 60,000 or 68,000 pounds ultimate strength, he deceives himself. The elastic limit is a matter which requires considerable study. Unless the engineer has the facilities and the opportunities for making comparative tests with all classes of materials, hard and soft, made by the same manufacturer, or by different manufacturers at different times, it is difficult for him to form a definite conclusion about the elastic limit of a given metal, to be safe in his structure. Prescribing the elastic limit as a percentage, like elongation and contraction, is more definite, provided the proper method is used in obtaining the elastic limit.

Another thing Mr. Campbell mentioned was that he wishes

the engineer to have more confidence in the manufacturer. In normal years we make at Altoona 20,000 tests and more. A great variety of material is received and I come in contact with manufacturers freely. I would always advise and caution every engineer to become intimately acquainted with the properties of metals, and to know more about them than the manufacturer himself does, as the latter cannot know all about the behavior of his material, because he does not see the behavior of his metal in service; still I believe Mr. Campbell is right in saying that the manufacturer should be trusted in certain details with which he is naturally more familiar, by reason of daily practice, than the engineer can be. There are things in physical metallurgy which cannot well be squeezed into the straight jacket of rigid, cast-iron specifications without making them top-heavy and unwieldy; some discretion might safely be left to the inspector, provided he knows his business, which, unfortunately, is not always the case. I have never yet been accused of flattery, but from my experience I am glad to say that I consider my superiors very wise in giving me a certain amount of freedom of action in accepting and rejecting material. I have used that freedom without ever hearing of a case in which it resulted detrimentally to the interest of the company, and I am sure the privilege has never been abused on my part. A certain amount of freedom of action accorded to a competent inspector (an incompetent one has no right to be either in the mill or testing room), results in mutual confidence and a spirit of co-operation between the parties, which is very gratifying.

Mr. Colby touched on the very important subject of the mechanical treatment of steel, and its results on the final quality of the steel. From fourteen years' experience in testing large quantities of new and old material of various grades, examining it in different ways, experimenting by forging and heating, bending and nicking, I believe that, while the chemistry of a piece of steel is the foundation it is built on, the mechanical treatment which that piece of steel has received, determines largely its value and suitability for a given purpose. No matter how well balanced the chemical constituents of a piece of steel, it can be made inferior or spoilt altogether by improper mechanical

treatment. The manufacturer who understands this part of his business thoroughly will come out ahead of all others.

Mr. Lewis remarked on the desirability of somewhat higher carbon steel, so-called middling hard steel, for structural purposes. I heartily agree with him in this. It is a great step forward to have this point discussed. Other things being equal, I believe that middling hard steel gives very much better and safer service where the structure is subject to shocks, vibrations and intermittent strains of all kinds. It is the degree of elasticity which determines the life and safety of structural material, and middling hard steel, such as described by Mr. Lewis, has a comparatively high elastic limit with sufficient ductility to act as a buffer, as it were, to neutralize the shocks and stresses imposed upon the metal. Such steel is therefore not so easily fatigued, and consequently not so liable to break in detail. However uniform a given steel may be, chemically and physically, however well treated and finished mechanically, if the elastic limit is too low, it is liable to be overstrained by any unforeseen or incalculable stress and give rise to unexpected breaks.

Mr. Christie very ably touched upon some very important matter concerning the methods of ascertaining the physical qualities and properties of steel. This matter deserves much more attention than it has received thus far. I believe that in everyday routine testing, it is quite out of the question to use elaborate instruments for determining the qualities of steel. But I consider it retrogression instead of progression to be satisfied with that crude method of determining that most important quality in structural steel, the elastic limit, namely by the drop of the beam; also to pay so much attention to the contraction of area, which is nothing more than the last gasp, as it were, in the dead struggle of the material, a period in the life of a structure which the engineer never contemplates seeing. In regard to taking the elastic limit with the drop of the beam, I think we are very much behind the times and are satisfied with a method not creditable to our intelligence and reputation. I have made hundreds of tests with the drop of the beam, and with the dividers at the same time; while I used the dividers, the man running the machine, who is quite expert in that matter, watching the

Let me call your attention to another point, namely, the elastic reaction taking place in iron and steel after it has been relieved of the stress that strained it. This elastic reaction may last for hours, for days or for weeks. You determine the elastic limit numerically, but the elastic reaction in your steel is an unknown quantity. Consequently if you determine the elastic limit by the drop of the beam, which means a highly disturbed stage in your metal, your structure is subjected to the load based on the elastic limit thus obtained, then it is, as I could show you, dangerously near the extreme limit of safety in some cases. Then the load, and with it the stress, is removed, but the elastic reaction still continues to agitate the metal and long, perhaps, before that agitation has ceased and the metal has assumed what might be called its normal condition, it is strained again, and if there is a constant repetition of this process, the metal never recovers fully, but is weakened before its time, and if a structure then breaks suddenly, or in detail, but unexpectedly, the engineer wonders what was wrong and some one talks knowingly about mysterious failures.

In connection with the elastic reaction, let me call your attention to some recent work done by the Royal Prussian Testing Department, in testing a large series of inch steel ingots (not hammered or rolled), containing various percentages of nickel, in which the limit of proportionality, the yield point and the elastic reaction are well shown.

NOTES AND COMMUNICATIONS.

PROPOSED WATER SUPPLY FOR PHILADELPHIA FROM SOUTHERN NEW JERSEY.

AT the meeting of November 21st, Mr. John C. Trautwine, Jr., made a few remarks on this subject. After referring to the various schemes for a new water supply, which have been brought forward, including those for drawing from the Susquehanna near Columbia, from Lake Erie, from the Schuylkill by the purchase of the works of the Schuylkill Navigation Co., from the Perkiomen, Tohickon and Neshaminy, from the upper Delaware, and from southern New Jersey, proceeded to a brief description of the water-sheds contemplated in the scheme last named, to some of which, during the day, he had paid a visit with Mr. Joseph Wharton, the proprietor of a large portion of the land embraced in them.

It is proposed to impound the head-waters of the Mullica and Great Egg Harbor Rivers and their tributaries (all of which are on the Atlantic slope of the divide) and to pump them across the divide into a reservoir to be constructed on the head-waters of Cooper's Creek, which enters the Delaware at Camden. Hence, after receiving some water from impounding reservoirs to be constructed on the head-waters of Rancocas Creek, they are to flow through a steel pipe laid under the bed of the Delaware to pumping stations on the Philadelphia side.

The crest of the divide is within a few miles of the Delaware. The water-shed is practically a desert, and the country is flat and sandy and is covered chiefly by scrub pines and cedar swamps. The latter give to the water a distinctly brown color when seen in mass, but the water is nevertheless, according to reports of the New Jersey Geological Survey, of exceptional purity and softness.

The principal obstacle to the accomplishment of this scheme is that it would involve the appropriation of the water of one State for the supply of a city in another.

The water-shed has been carefully examined by Mr. C. C. Vermeule, Topographical Engineer for the State Geological Survey of New Jersey, who, in a report to Mr. Wharton, gives the following data respecting the several water-sheds, and who estimates the cost of a supply of 300 million gallons daily at about 15 million dollars, including real estate, extinction of water rights, and rights of way.

	Water-Sheds.		Storage Reservoirs.	
	Area, square miles.	Minimum daily yield from storage reservoirs. Gallons.	Elevation above tide, feet.	Storage capacity. Gallons.
Mullica River.	359.7	240,000,000	70 30	25,284,000,000 18,138,000,000
Great Egg Harbor River.	215.2	143,800,000		13,267,000,000
Rancocas Creek.		13,100,000		
Cooper's Creek.			61	2,000,000,000

Owing to the flatness of the country, the flow of the streams is quite sluggish, and although the ground, owing to its sandy nature, is very retentive of moisture and thus acts to a great extent as a natural storage reservoir, the summer flow of the streams in question would be quite inadequate to such a supply as is contemplated, and would therefore require the construction of numerous storage reservoirs of considerable area, though of moderate elevation and depth, and therefore of relatively inexpensive character.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, November 7, 1896.—President A. Falkenau in the chair. Seventy-three members and visitors present.

Mr. Allen J. Fuller presented the first paper of the evening, on "Queen Lane Division of the Philadelphia Water Supply System.—IV. The Distributing System," and illustrated his remarks with lantern slides and blackboard sketches.

Professor L. F. Rondinella then read a paper on "Rapid Methods in Instrumental Drawing," illustrated by lantern slides and models.

Regular Meeting, November 21, 1896.—Vice-President John L. Gill, Jr., in the chair. Seventy-five members and visitors present.

Mr. Charles Piez read the paper of the evening on "Professional Ethics Among Engineers."

The Tellers reported that, at the election of this date, Messrs. Charles Albertson, Joseph Appleton, Charles Hexamer, Harry K. Myers, E. M. Nichols, Tinius Olsen, Edwin S. Philips, Joseph W. Silliman, Gustave A. Stierlin and W. S. Twining, had been elected to Active Membership, and Mr. Frank G. Rowbotham to Associate Membership.

Mr. John C. Trautwine, Jr., made some remarks, illustrated by a map, on a "Proposed Water Supply for Philadelphia from Southern New Jersey." (See under *Notes and Communications*).

Business Meeting, December 5, 1896.—President Arthur Falkenau in the chair. Eighty-two members and visitors present.

The President announced the death of Mr. Amasa Ely, Active member, which occurred on the morning of December 2d, and then invited Mr. Trautwine, Chief of the Bureau of Water of Philadelphia, in which Mr. Ely was employed, to address the Club in regard to Mr. Ely and his death.

Mr. Trautwine thanked the Club for the opportunity to speak, in justice to Mr. Ely, since the fact that Mr. Ely had testified in the suit now pending between the City and the contractors for the Queen Lane Reservoir, and, that on the next day, when he was to have appeared again on the stand, he took his own life, would naturally suggest the existence of matters of which he was aware and which he feared, on his own account, to reveal. Mr. Trautwine then read a letter, which he had sent to the Director of the Department of Public Works, for subsequent publication. This letter stated that, so far as the writer could learn, Mr. Ely's official record is absolutely free from all shadow of stain, that he was an assistant of the greatest value, and one whose business and private life were both exemplary. His suicide was probably the result of prolonged nervous strain acting upon a relatively frail organization. Mr. Trautwine also read a letter from Judge A. M. Beitler, late Director of Public Safety, testifying to Mr. Ely's sterling worth, and stating that every one who knew him will feel that it was mental overwork and worry alone which drove him to the rash deed he committed; and another from Messrs. Booth, Garrett and Blair, in which it was stated that Mr. Ely impressed everybody who came in contact with him as a man of sterling character and engaging manners. In a letter from Major C. W. Raymond,

U. S. Engineer (who was associated with Mr. Trautwine and Mr. Rudolph Hering in the investigation of the Queen Lane Reservoir in 1895), it was stated that, after a large experience with assistant engineers, he had never seen one in whom he had more confidence or for whom he felt greater respect. In closing, Mr. Trautwine stated that, while he was glad to bear his official testimony to Mr. Ely's character, there were other gentlemen, particularly Mr. Frank L. Hand, his immediate superior, who stood in far closer relations with him, and therefore knew him better.

Mr. Hand stated that he had been associated with Mr. Ely during the past ten years in the construction of the East Park, Roxborough, and Queen Lane Reservoirs, and that instructions given to Mr. Ely were always carried out conscientiously and honestly. He was a noble young man, and, had he lived, would doubtless have attained a position of eminence. He had nothing to conceal with reference to his business transactions, and his domestic affairs were of the happiest nature. In his death the City has lost a faithful servant, and the Club a valuable member.

Upon motion, duly seconded and carried, the President was requested to appoint a committee of three to prepare a suitable memorial of Mr. Amasa Ely, and he subsequently named, on that committee, Messrs. L. Y. Schermerhorn, John C. Trautwine, Jr., and F. L. Hand.

Nominations for officers for 1897 were presented in writing in the form prescribed by the By-Laws and reported by the Secretary as follows :

Nominee.	Proposer.	Seconder.
	President.	
John L. Gill, Jr.	H. W. Spangler.	Edw. K. Landis.
Jos. T. Richards.	L. Y. Schermerhorn.	Carl Hering.
Edgar Marburg.*	Wm. C. Furber.	J. C. Wilson.
	Vice-President.	
Henry Leffmann.	George T. Gwilliam.	John L. Gill, Jr.
Wm. C. Furber.	Jos. T. Richards.	Jas. Christie.
	Secretary.	
L. F. Rondinella.	H. W. Spangler.	Edw. K. Landis.
Edwin R. Keller.	P. A. N. Winand.	P. F. Leach.
	Treasurer.	
George T. Gwilliam.	John L. Gill, Jr.	Max Livingston.
	Directors.	
G. B. Hartley.	H. W. Spangler.	Edw. K. Landis.
C. H. Ott.	J. C. Trautwine, Jr.	John L. Gill, Jr.
F. Schumann.	Max Livingston.	I. R. Newkirk.
Wm. C. L. Eglin.	Minford Levis.	F. Uhlenhaut, Jr.
Gratz Mordecai.	H. W. Spangler.	Edw. K. Landis.
Thos. H. Mirkil, Jr.	C. L. Prince.	F. Schumann.
Jos. C. Wagner.	R. L. Humphrey.	H. B. Osbourn.

Mr. L. Y. Schermerhorn stated that the Membership Committee had met with considerable difficulty in deciding upon the eligibility of applicants for membership

* Since declined by Prof. Marburg as unauthorized.

under our present By-Laws, and its three members had, therefore, prepared some amendments, which they offered to the Club with the approval of the Board of Directors. He explained that the most important changes were the raising of the standard of admission to Active Membership, and the creation of the new class of Junior Membership, to which graduates from reputable technical schools would be immediately eligible, and from which they must be transferred to Active Membership upon becoming eligible therefor.

Mr. Charles Hewitt then presented the paper of the evening on "The Application of the Storage-Battery to Electric Traction."

REGULAR MEETING, December 19, 1896.—President Arthur Falkenau in the chair. Ninety-five members and visitors present.

The Secretary announced the death, on December 9th, of Mr. O. E. McClellan, Active Member of the Club.

A topical discussion on the subject of "Some Open Questions Concerning Structural Steel" was participated in by Messrs. H. H. Campbell and Albert Ladd Colby, who spoke on "The Influence of Various Agencies in the Course of Manufacture;" by Mr. Frederick H. Lewis on "The Practicability of Using Higher Carbon Steels;" by Mr. James Christie on "The Influence and Effect of Dynamic Stresses on Material and Structures;" and by Mr. Colby, again, on "The Practicability of Using Higher Carbon Steels for Forgings."*

Mr. G. C. Henning exhibited and described accurate instruments of his own invention for use in testing steel and for recording stresses and strains in such tests. Mr. Kreuzpointner also made some remarks upon the results of tests of steel made in the testing department of the Pennsylvania Railroad.

Upon motion, it was resolved that this discussion be continued at one or more future meetings, and the thanks of the meeting were tendered to the visitors who had taken part.

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* The titles of some of these remarks were changed by the authors in the revision before publication in the present number of the PROCEEDINGS. [PUB. COM.]

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

SPECIAL MEETING, November 7, 1896.—Present: President A. Falkenau, Vice-President Gill, Directors Furber, Leffmann, Marburg, Livingston and Schermerhorn, and the Secretary.

The meeting was called to consider the resignation of Miss Steel, from the position of Office Assistant.

REGULAR MEETING, Saturday, November 21, 1896.—Present: President Falkenau, Vice-Presidents Gill and Hering, Directors Leffmann, Richards, Schermerhorn; the Secretary and Treasurer.

The Treasurer's Report showed:

Balance from September	$464 34	
Received during October	569 25	
		$1033 59
Expended during October		602 01
Balance October 31,		$431 58

Resignations were read and accepted from Messrs. Wm. Biddle, L. P. Gaston, and H. M. Montgomery from active membership; and A. Brockerhoff, from associate membership.

The Secretary read a proposition from Messrs. Armstrong and Fears, dated November 20th, in which they offered to furnish the Club with 600 copies of the list of members for 1897, with Charter and By-Laws if desired, bound the same as those of last year, without cost to the Club, they to have the right to insert advertisements opposite each page, and the title page, in the list of members, and in the front and back of the book. This proposition was accepted with the proviso that the character of the advertisements be the same as agreed upon for the Proceedings.

The Secretary raised the question as to whether new members should be entered upon the books of the Club immediately after election, or not until they had paid their first year's dues, and upon motion it was ordered that new members shall be entered upon the books of the Club immediately after their election.

After some discussion, it was resolved that $150 be appropriated to purchase 75 chairs of the pattern exhibited by sample, for use in the Club's meeting room.

It was moved and carried that the House Committee be instructed to obtain one frame to hold the pictures of the five past Presidents.

SPECIAL MEETING, Saturday, December 5, 1896.—Present: President Falkenau, Vice-Presidents Gill and Hering, Directors Furber, Schermerhorn and Livingston, the Secretary and the Treasurer.

The meeting had been called to consider the new amendments to the By-Laws, which the Membership Committee had proposed. Mr. Schermerhorn presented the suggested amendments. After some changes, it was ordered that these amendments be reported to the Club as endorsed by the Board of Directors.

REGULAR MEETING, Saturday, December 19, 1896.—Present: President Falkenau, Vice-President Gill, Directors Leffmann, Marburg, Schermerhorn and Furber, the Secretary and the Treasurer.

The Treasurer's Report for November showed:

Balance from October	$431 58	
Received during November	315 00	
		$746 58
Expended during November.		327 18
Balance November 30		$419 40

The resignations of Messrs. R. I. D. Ashbridge, Ira A. Shaler and Wm. Rhodes, were presented and accepted.

The question of the proper method of approving bills was discussed.

ADJOURNED MEETING, Wednesday, December 23, 1896.—Present: President Falkenau, Vice-Presidents Gill and Hering, Directors Richards, Marburg, Leffmann, and the Secretary.

The House Committee was instructed to meet at least once each month, except during the Summer recess.

For the Committee to audit the Treasurer's Accounts for 1896, the President appointed H. C. Lüders, Jas. Christie and W. P. Dallett, and Mr. Edward K. Landis an alternate Auditor.

The President appointed as a Committee to prepare the Annual Report of the Board of Directors, Messrs. Henry Leffmann (Chairman), John L. Gill, Jr., Carl Hering, W. C. Furber, Edgar Marburg and L. Y. Schermerhorn.

The methods of approving bills were discussed.

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FROM AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

Transactions, Vólume II, 1896.

FROM AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Volume XVII.

FROM A. FALKENAU.

Report on The Use of Metal Railroad Ties, etc.; Tratman.
Elementary Lessons in Electricity and Magnetism; Thompson.

FROM GOVERNMENT PRINTING OFFICE.

The Official Gazette of United States Patent Office, containing Patents, Trademarks. Designs and Labels.

FROM HISTORICAL AND SCIENTIFIC SOCIETY OF MANITOBA.

Annual Report, 1894.
Annual Report, 1895.
Worthies of Old Red River; Bryce.

FROM INSTITUTION OF CIVIL ENGINEERS, LONDON.

Abstracts of Papers in Foreign Transactions and Periodicals.
Annual Report of Chief of the Bureau of Steam Engineering.
Annual Report of the Director of the Board of Trustees.
Columbian Museum; Field.
Four American Rolling Mills; Wellman.
General Treatment of Paper after Manufactured.
The Liverpool Water Works; Deacon.
Manchester Water Works; Hill.
Manufacturing Steel Plates; Head.
Military Outport at Liban; Jauntzoff.
New Form of Dual Drainage; Godfrey.
The Super-Elevation Tape; Buck.
Thermal Efficiency of Steam Engines; Sankey.
Transport of Live Stock; Chaimberlain.
Transport and Storage of Grain; Britton.

FROM DR. LEFFMANN.

Das Wasserwerk der Freien und Hansestadt Hamburg; F. Andreas Meyer.

FROM MACMILLAN & CO.

Computation Rules and Logarithms; Holman.

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Drains and Sewers.
Dressing and Finishing Woven Manf. Felted, Including Folding, Winding, Measuring and Packing.
Electric Telegraphs and Telephones.
Fastenings, Press, Jewelry.
Filtering and Otherwise Purifying Liquids.
Grain and Seeds, Treating.
Grinding, Crushing, Pulverizing and the like.
India Rubber and Gutta Percha.
Instruments and Materials.
Iron and Steel Manufacture.
Music and Musical Instruments.
Paper, Leather and Fabrics.
Philosophical Instruments, Optical, Nautical, Surveying, Mathematical, Meteorological.
Printing other than Letter Press or Lithographic.
Railways and Tramways.
Sewage; Treatment of.
Shop, Public house and Warehouse Fittings and Accessories.
Sifting and Separating.
Wearing Apparel.
Wood and Wood Working Machinery.

FROM STATE BOARD OF HEALTH, MASSACHUSETTS.

Twenty-seventh Annual Report, 1895.

FROM SYRACUSE WATER BOARD.

Seventh Annual Report, 1896.

FROM UNITED STATES GEOLOGICAL SURVEY.

Sixteenth Annual Report and Papers of a Theoretic Nature.
The Production of Iron Ores in 1895; Birkinbine.

PROCEEDINGS

OF THE

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OF

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ENGINEERS' CLUB OF PHILADELPHIA.

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I.

THE ENGINEER AS A MORAL FACTOR.

ANNUAL ADDRESS BY THE RETIRING PRESIDENT, ARTHUR FALKENAU.

Read January 16, 1897.

THE modern and inevitable tendency to specialization is fraught with baneful influences, which seem to prevent the *broader* development necessary for a true conception of the meaning of life. The ideal development of man lies in the even growth of all his faculties, and if we would attain the highest purpose, we should be men before we are doctors, merchants, lawyers or engineers. The most beautiful tree, be its special function to bring forth the acorn or the golden orange, is the one whose branches are symmetrical, whose foliage is luxuriant and whose growth is harmonious. Though weighted with the finest fruit, it has developed its leaves and branches and forms a perfect whole. Why should it be any more necessary in human nature than in the beautiful nature surrounding us everywhere, that when it unfolds, the weight of the fruit it bears should be so distributed as to distort it from all semblance to its species or that its strength should be sapped to the detriment of all other capabilities? Is it that the demands made on us by the requirements of modern existence are greater than we can possibly bear?

Careful consideration will refute such a supposition. Let a seed fall in rich soil. Let the young plant be nursed by rain and sunshine, and every power of nature aid in maturing it; then we may expect a perfect plant. So, too, with the human individual. Where his natural endowments are the best and his environment and cultivation most conducive to his growth, there shall we find the most perfect being.

There is, however, one great distinction. The human being is not helplessly subject to the conditions imposed by nature. He is possessed of independent will and can largely create his own circumstances. There are forces under his control,—physical, intellectual and moral. He may not be able to shape material conditions in the mould he fancies most, but of himself he is the king. It is for him to develop to the utmost, what germ of the divine spirit is in him. Not only is his attitude toward himself important in its bearing on his growth, but it determines his direct influence on the community and the nature of that subtle impress on the world which each life leaves after it has passed away.

We are apt to think that the inheritance from ancestors of the engineering profession, and the environment of engineering activity, are the best and almost only circumstances which can produce great engineers. That this is not always true, is illustrated by the lives of Nasmyth, Fulton, and others. More important to create the inspiration which makes the great engineer are the moral forces, the veneration of truth, and the aim of idealism. A love of literature or art may foster these as well as an innate love of science. It may be contended that this inspiration gained from art or literature could be sought with reasonable comfort in the days of the famous engineers just mentioned; that now the need of acquiring minute and special engineering knowledge does not leave room for aught else. It is forgotten that the increase of facilities for gaining knowledge has kept pace with the growing demand.

In the early part of this century engineering courses were unknown, and the majority of engineers had no scientific training, but that acquired by dint of close application to such books on natural philosophy, chemistry and mathematics, as were

available. If one was so fortunate as to enjoy a scientific education at a university, it was so broad as to require much extra work on the part of the student to adapt it to the profession of engineering. Surely the modern system, which presents intellectual dishes already prepared to suit every taste, should set much time free which was formerly spent in the cooking.

In the present age we are more highly favored. The shaping of our course is not so much the sport of fortune, nor is it left to the erratic and uncertain judgment of parents. Every opportunity is given to discover the bent of a young man's mind, and well organized schools exist everywhere to assist in moulding and training the young engineer. How far his latent possibilities shall be developed, will depend as much on the moral as the intellectual force of the teacher of enginering. He, more than any other, has it in his power to encourage high aims, to instil a noble conception of the calling, and to inspire enthusiasm. It is a work of great reponsibility which the teacher assumes, and many there are who have applied themselves with untiring energy to the highest and truest development of the subject of their devotion, and have earned the deserved recognition and faith of mankind. They, more than any other class of our community, are free from that modern curse—the pursuit of wealth —which when it attacks even the greatest genius, produces atrophy. It is evident that Faraday clearly realized this fact. Tyndall tells us that at a time when great opportunities for amassing a fortune presented themselves to Faraday, he felt he had to choose between wealth on the one side, and undowered science on the other. He chose the latter and died a poor man. He carried his singleness of purpose and loyal devotion to science to such an extent that when the presidency of the Royal Society was offered him, he refused it in the following words: "Tyndall, I must remain plain Michael Faraday to the last, and let me now tell you, that if I accepted the honor which the Royal Society desires to confer upon me, I would not answer for the integrity of my intellect for a single year."

Although the American has been justly accused of too great a worship of mammon, I am glad to believe our teachers of both pure and applied science are fast learning to take the attitude of

the pursuit of science for science's sake, which characterizes so many of their European brethren. Nevertheless there are many who follow teaching merely as a bread-calling, and live in the hope of attaining to some lucrative position, their real aim being concentrated on material gain. They perform their work in a mechanical manner, grinding out the conventional engineer, cramming the student's mind with facts and propagating in him the same errors and lack of high ideals which have chained *them*, otherwise talented individuals, to a low plane of usefulness. Unfortunately this class of teachers is sufficiently large to tincture the whole educational system with its perverted views. Too much stress is laid upon the mere perfunctory acquirement of knowledge. The teacher should encourage doubt and original thought in the student's mind; without these, truth in all its glory cannot be realized. The appreciation of the fundamental truths in science will awaken an admiration and enthusiasm, which will not only color the entire moral life, but which will also, from a purely practical and material point of view, produce the greatest results.

The old contest between the humanities as embodied in the classic courses on the one side, and science as represented by the various special courses on the other, is still being waged. The broadening influence of the humanities cannot be denied, and I believe will ultimately receive recognition in connection with a scientific education, although in a greatly modified form from that advocated by its vehement supporters. A literary man who has taken his degree in arts, has not only received in the course of his study of Latin, Greek, literature, history and philosophy, the tools to be used in his future life work, but has imbibed almost unconsciously the moral influence of Plato and Marcus Aurelius, of Greek art and Roman intellect, of the immortal poets of Italy, Germany and England. So in history and literature, thoughts and memories which remain to him are centered about living, breathing beings. The force of example bears in upon him everywhere. He sees what man can be and do, and his fire of enthusiasm is kindled thereby. He selects his hero, his model. How great the value of reaching this point is, can only be fully appreciated by understanding the truth which

Emerson has expressed in these apt words: "The youth intoxicated with his admiration of a hero, fails to see that it is only a projection of his own soul which he admires." This germ of a high and noble purpose, although it be only an unconscious possession, becomes a nucleus about which ideas reaped by the student in his daily work are grouped and rounded into a harmonious whole. The study of the biography and history of the engineering world, if introduced in an engineering course, would keep the student more in touch with human nature, increasing his self-trust and inspiring him with higher and broader aims. This might be a small step in the direction of admitting the humanities, and would appeal to those opposed to any but scientific studies in an engineering curriculum.

When a student emerges from that bright elevating atmosphere which envelops all true institutions of learning, and meets with the apparently cold, hard life of the business world, the hold on the high ideals he has formed is put to great strain, and frequently his views become distorted, if the ideals are not entirely wrenched from his grasp. It is then that his understanding of the principles of the studies he has pursued and the earnestness of his purpose are put to the test. The young engineer, in his daily work, is confronted with perplexing problems. He finds that in constructing earth works, building machines, or developing mines, he is met at every hand with so many practical considerations that it almost seems that the many years he has devoted to study have been wasted. He finds that his theoretical knowledge is frequently misapplied, that he of practical training outstrips him, that he is losing time and suffering useless anxiety in attempting to make use of theory, where practical considerations outweigh the former, and lead to a quicker accomplishment of the duty before him. This struggle goes on for a time until he becomes confused and even skeptical. Nor are these moral effects solely confined to the pursuit of his calling. His whole moral being is severely shaken. He casts doubt not only upon the application of scientific principles to practical engineering, but on those broader principles which are to solve the problem of life itself. He begins to believe that selfishness and meanness are better calculated to lead to advancement than those ideals

which have been formed during his warm fellowship of college days. The engineers he meets refuse that free interchange of thought which so enriched his student life. He is everywhere confronted with the notice, "No admittance," and it appears to him that his neighbors actually delight in strewing his path as thickly with thorns as possible. It is gratifying to know that this spirit of exclusiveness and jealousy is not nearly as pronounced as it was years ago. The young engineer needs encouragement and the fellowship of his more experienced brethren. Nor is their duty towards the novice without its reward. The world is ever new, and thoughts which may have lain dormant in an older field may bear rich fruit when transferred to the fresh soil of the young and active brain. If the engineer be placed in a position giving him command of other men, he is led to think that he must learn how to be hard and unsympathetic. It is sometimes thought that to have sentiment is not manly. Puerile or morbid sentimentality is very different from a strong fellow-feeling. No one has ever lost in true self-development by holding fast to the manly sentiments of human fellowship, by jealously guarding integrity even at the expense of temporary or apparent retardation. The saying that business and sentiment do not mix is undoubtedly true, if we accept the definition of the former as being that scientific adjustment of circumstances and transactions which will result in the greatest pecuniary profit. In such transactions, the natural laws of business should receive the first consideration, but should be closely followed and modified by worthy sentiment.

The object of business is the making of money in an honorable manner, but it is secondary to the object of life, which is the development of the highest and best that is in us. If after many disappointments and long deferred hopes, a position of responsibility is attained by the engineer, he meets with new trials and greater temptations. If he has not the courage to face his responsibilities fairly, he may seek to shirk them, and place them where they do not belong. To adopt such a course would be cowardly. A frankly acknowledged failure commands respect and may in the end prove a stepping stone to success. If the mercenary spirit is strongly developed, opportunities for taking and giving bribes are quickly discerned. Then danger is at

hand—ruin of the man is imminent. If he yields, all the latent possibilities with which he may be endowed, if not absolutely crushed under the weight of the ill-gotten gold, are at least blighted in their growth. His development can never be what it would have been had he scorned temptation, and placed honor and principle above all else. The time comes to most men when they must choose between worldly welfare and being true to themselves. Superiors may demand of the engineer, the sanction or commission of deeds which his conscience cannot approve. How often do we hear of bribes offered, to induce the purchase of supplies or machinery, the false measurement of stone or earthwork, to permit the departure from specifications or to make a glowing or false report on the test of some new invention, or on the capacity of some engineering structure? Often these same objects are sought to be attained not only by bribery, but by pressure or command from superiors, the influencing consideration being the loss of a position. When the sacrifice of principles, integrity and self-respect are at stake there can be but one true course—the engineer must resign.

Before the Civil War a league was entered into by Southern merchants, not to purchase goods of those who were not of their party. Circulars were sent to all the Northern importers, informing them that if they did not withdraw from all connection and sympathy with the anti-slavery movement of the North, their trade with them would cease. Be it said to the credit of the majority of the merchants of that period, which tried the metal men were made of, the answer came unhesitatingly, clear and distinct—we sell our goods, not our principles. So the engineer may sell his services, but never his principles. Unfortunately, in the business world of to-day, evasion, trickery, deception, the use of bribery, the abuse of confidence, and even theft, are not only winked at, but under the euphemisms smartness and shrewdness, are admired. Thus, the unjust interpretation of contracts is frequently resorted to, merely as a pretext for obtaining a pecuniary advantage. No doubt, at times, when taken by the letter, the demands made by contracts may be over-exacting. When this occurs, equity can only be attained by aiming to carry out the spirit of the agreement. Great caution and conscientiousness

sider every element of strength and weakness of a boiler, and admits of the inspector using his, perhaps, faulty judgment.

To be more definite, in Kings County (N. Y.), which includes Brooklyn, the following is the rule: "The inspector will apply the following rule in fixing the limit to be allowed on such boiler or boilers: Multiply one-sixth of the lowest tensile strength found stamped on any plate in the cylindrical shell by the thickness, expressed in inches or parts of an inch, of the thinnest plate in the same cylindrical shell, and divided by the radius or half-diameter, also expressed in inches, and the same will be the pressure allowed per square inch for a single-riveted boiler, to which add 20 per cent. for a double rivet." (This riveting refers to the longitudinal seams in a horizontal boiler, and, of course, to the vertical seams in a vertical boiler.) By this, the inspector is compelled to accept, without question, the stamp on the material—the higher the tensile strength, the greater pressure would be allowed; this tensile strength could be run so high as to make the material totally unfit for boilers, yet permit of the inspector issuing a certificate allowing an extremely high pressure, and this for a boiler even with single-riveted joints. The one designing and drawing up specifications, if he knew no better, would ponder over the advisability of considering a high tensile strength with single-riveted seams, or a lower tensile strength with double-riveted longitudinal seams. This is absurd, yet, as will be seen by the foregoing, permissible. Now, for the 20 per cent. additional when the seams are double-riveted. Unquestionably, the weak point in a cylindrical boiler-shell is the joint, and the rivets should be of the proper size and of the proper spacing apart, to allow the joints to be of as high percentage, compared with the solid plate, as possible. Once upon a time it was thought that the more rivets there were in a joint, the stronger it would be, regardless of the number of holes punched in the sheet, thus unknowingly causing a double-riveted joint to be weaker than a single-riveted one, if the rivets in the latter were properly spaced; yet, Kings County boilers are allowed 20 per cent. additional under these adverse circumstances. Insurance companies, inspecting boilers, must keep within the laws governing the same; in this case, they are compelled to do so as a matter of self-pro-

[Proceedings Engineers' Club of Philadelphia, Vol. XIV, No. 1, April, 1897.]

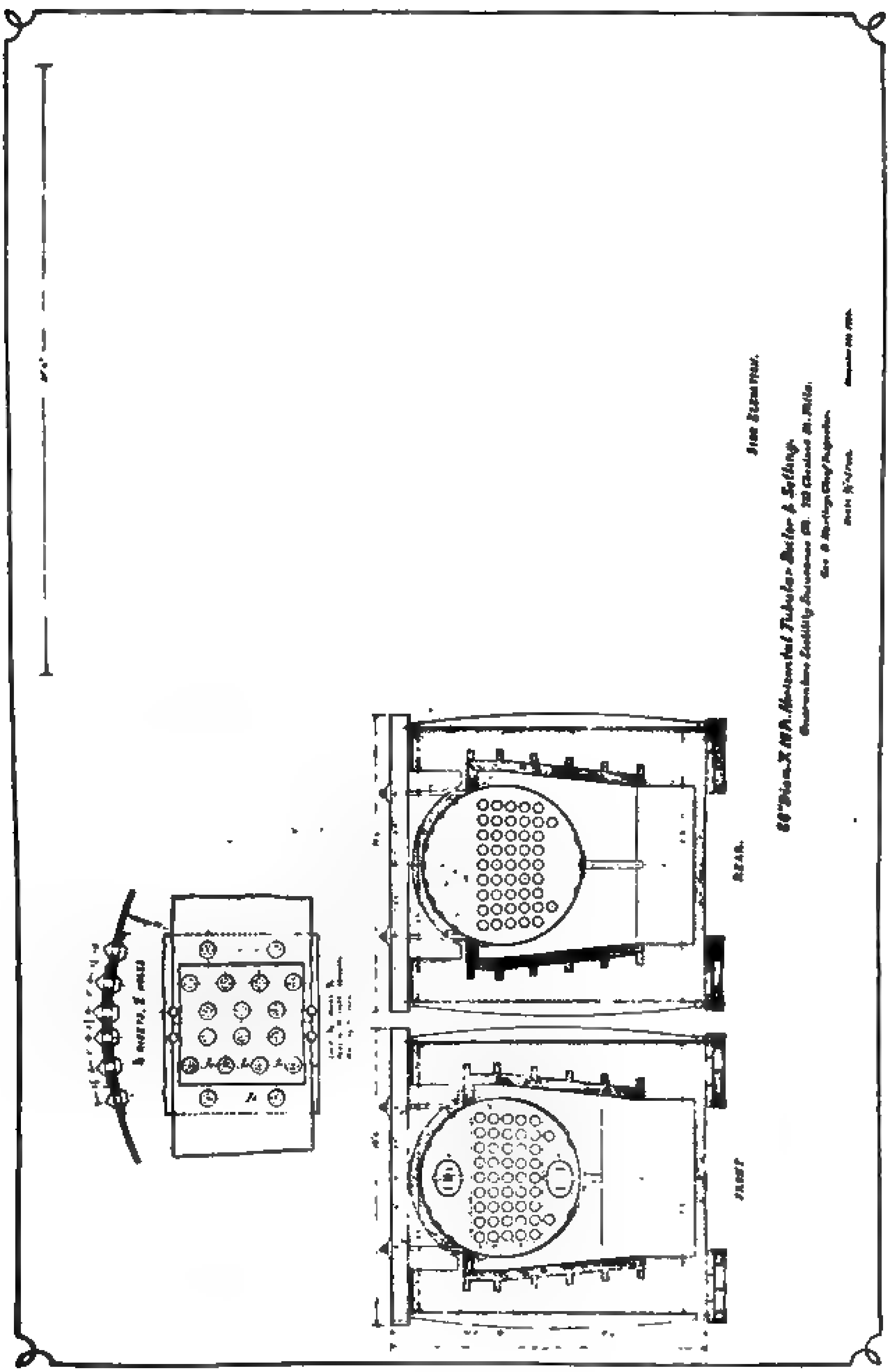
Boiler Clogged with Scale, Proving Inefficiency of Hydrostatic Pressure to Determine Condition of Boiler, this having been Applied for 6 Years before an Internal Examination was Made.

being of cast iron, besides the multiplicity of joints and connections, also objections on the part of the manufacturers of the older types and the usual unwillingness to accept something new. Nevertheless, the horizontal tubular boiler will soon be a steam-generator of the past; being externally fired, it is limited in thickness of sheets and consequently in diameter, so that in a boiler of this type the pressure and power is limited. This furnishes additional encouragement for boiler manufacturers to turn their attention to the making of more perfect sectional boilers, not only for stationary purposes but for marine uses also; for instance the boilers of the "St. Louis" and "St. Paul."

I call your attention to the following dimensions of the boilers of these ships. Each ship contains ten boilers, six of which are double-ended, 15′ 7½″ in diameter by 20′ long and containing furnaces each; the other four are single-ended, of the same diameter, 10′ 6″ long, with only four furnaces,—making a total of 64 furnaces.

The weight of each boiler, exclusive of smoke-boxes and fittings, being 206,500 pounds, this boiler containing 112,000 pounds of water when under steam, or, summing a total—the weight of all ten boilers including water in each is 1654½ tons. It is unnecessary to speak of the loss of so much valuable ship space occupied by these steam-generators. The shell plates of these boilers are of $1\frac{9}{16}$ thickness, which, with their diameter, permits of a pressure of 200 pounds per square inch. Neither weight of metal nor skill and strength required in the construction of these types will permit this pressure to be exceeded. We therefore have four important reasons for the development and adoption of a water-tube boiler for marine uses: first, to obtain less weight and more space; second, less first cost and less cost of repairs; third, economy of operation in the development of high pressures; and lastly, reducing the danger of explosions to a minimum.

The boilers for the yacht "Alva," built by Harlan & Hollingsworth, Wilmington, Del., have the following dimensions: Diameter, 17′ by 10′ long; thickness of shells, $1\frac{1}{8}$″; heads, $\frac{7}{8}$″ thick; tube-sheets, $\frac{3}{4}$″ thick. Number of tubes, 298, 3½″ in diameter, heating surface equalling 1736 square feet; four furnaces, 44″ in



A Modern Horizontal Tubular Boiler Capable of Sustaining a Working Pressure of 130 Lbs. per Sq. Inch.
The Method of Suspension a Desirable Feature.

In turning to the stationary boilers, a wider field of choice is presented for higher pressure, as, in addition to the water-tube type, there are several designs of internally-fired boilers. From an economical standpoint, there is little difference between the two, notwithstanding the claims and reports of efficiency tests advanced by the makers of patent boilers. There are but so many heat units in a pound of coal, and how to impart this heat to the making of steam is the problem.

It would seem that the internally-fired boiler, properly proportioned, so that steam-making heat is not wasted in the chimney, is the solution. Again, this type possesses the advantage of a large disengaging surface and plenty of steam space, and can be built to carry a working pressure as high as there will ever be necessity for, making it desirable for large plants, namely: electric power-houses, breweries, water-works, sugar refineries, etc.

The water-tube boilers necessarily lose considerable heat by reason of the brick-work setting, which latter must be kept in good repair or the loss becomes excessive, while the disengaging and steam space in the designs to date is believed by many to be a detrimental feature.

I introduce at this point, as a matter of comparison, another reason for the passing away of the old types, and one which may in a measure apply to the internally-fired boilers just now referred to; that is, the cost of repairs. When a defect is found, it often necessitates half rims, new sheets in fire-boxes, removal of braces, screw-stays, etc., and frequently the tubes, thus naturally increasing the actual cost of repairing the boilers to a considerable amount, besides enforcing a long idleness of the plant. It simply appalls the owner of an establishment when compelled to shut down and lay off his numerous hands for the time being; whereas, if he had a water-tube boiler, all sections of which can be duplicated at short notice, the saving would prove more by far than the additional first cost of the water-tube type. This will apply forcibly to marine boilers. The modern ocean-steamer, representing a million and a-half of capital, must lie idle at a dock while putting the present type of boilers in condition, as well as taking off this valuable vessel from its regular service. For these reasons our boiler manufacturers must revolutionize their business, not

for the sake of economy, which is the false battle-cry offered by the patent boiler people, but for the sake of higher pressures, and economy of keeping in serviceable condition.

Naturally, the feed-water is important. To permit the use of pipe boilers where the water is impure, methods far in advance of those now in use must be adopted. This is a question that should receive more careful attention. Water should be made pure by filtration and chemical treatment before it goes into the boiler; this latter is a wide field for research, and, with the coming boiler, a profitable one.

Perhaps it would prove interesting to show another type of internally-fired boiler, adopted by the Calumet and Hecla Mining Co., of Michigan, they having over forty in use. This boiler is known as the Bellpaire Fire-Box Type.

The dimensions of the one shown are: Cylinder, 90″ in diameter; length of boiler over all, 34′ 4″; weight of boiler, 86,000 pounds, exclusive of fittings.

Boiler contains two fire-boxes, connecting into one so-called combustion chamber, after which the heat is continued through 201 three-inch tubes, 16′ long.

The shell-plates are of $\frac{3}{4}''$ steel; plates exposed to heat, fire-box, etc., are of $\frac{1}{2}''$ and $\frac{9}{16}''$ thickness. The extensive staying and bracing necessary is a noticeable feature. The average pressure is 180 pounds. Bituminous coal and wood used as fuel.

I understand this type of boiler was adopted, because of the excessive vibration from the ore-stamps destroying brick-work settings of other designs.

In coming directly to the inspection of boilers the insurance agent visiting a plant rarely finds that the boilers have been gotten into proper condition to permit of a thorough examination. Too often the steam-user is loath to spare the necessary time for the boiler to cool properly, and be cleaned out. The inspector then is confronted by a disagreeable task. The boiler, being excessively hot, limits the time he can stay in it, while what is termed the combustion chamber contains two or three feet of dust and ashes, grate-bars not being removed; in fact, all that has been done is the emptying of the boiler and the taking out of the man-hole plates. Too many owners of manufacturing

establishments do not take the interest in these particulars that is demanded; it follows to their disadvantage, meaning to them a waste of fuel and loss of power, by reason of failure to remove the scale, while defects are liable because of the hasty emptying of the boilers before the walls are cooled.

Assuming that the boiler has been gotten in good shape for examination, the inspector will possibly find the following, which are the more common ills that steam generators are heir to:

INTERNALLY.—Corrosion, the different forms of which may be termed uniform wasting, pitting or honeycombing, and grooving. Uniform corrosion is found where the circulation is most rapid. I have inspected numerous two-flue boilers in southwestern Pennsylvania, where almost every stream is polluted with sulphur-water, pumpings from mines, in which the sides of the flues, as well as the sides of the shell at the front ends, are as may be termed "washed away," yet unnoticeably, and only to be detected by the hammer.

In other parts, such as the extreme rear end, and in mud-drums, or in the water-legs of locomotive type boilers, the pitting and honeycombing take place, to better illustrate which I have two specimen plates. This latter defect is so apparent as to be readily discovered, thus preventing serious results.

The most serious form of corrosion is that which attacks the plates along the water-level, forming a continuous line of weakness, to which a number of explosions have been traced. It is unnecessary to add that all this is due to acids in the feed-water, the only remedy of which is to change the supply to pure water. I recall an instance in the Connellsville coke region, where the Youghiogheny River became so low during the dry season as to uncover the ends of the water pipes, and the pumpings direct from the mines had to be used in the boilers; to neutralize the effects of the acids, lime was mixed with the water pumped into the boilers. It was thought necessary to do this every other day until the river had again risen, at which time inspection proved that, with the exception of some light pitting on the bottom rear plate around the blow-off, the boilers were not injured; while, at another plant, the use of the direct pumpings from the mines, without this treatment, practically destroyed the boilers in ten days.

It is more difficult to detect external corrosion than internal, as it usually takes place where the boilers are bricked-in at the fire-line, or on the top plates where the boilers are also covered by the brick-work.

Frequently, grooving is found along the girth-seams along the bottom; this is often due to the caulking leaking, which is not noticeable when the boiler is not in use. Often, in long cylinder boilers, the leaks are occasioned by the lower parts being subjected to heat, while the upper parts are exposed to the atmosphere, thus causing unequal expansion, or, in heavier boilers, the double thickness at the laps springing the caulking.

The inspector, in looking over the older boilers, expects to find these groovings, the primary cause being often in the use of what is known as a split caulking tool, creating a groove by breaking the skin of the metal.

Another frequent discovery is buckled or bagged sheets, the result of neglect in keeping boilers properly cleaned. A quantity of scale accumulating on the sheet over the fire, to which point it is carried by the circulation of the water in the boiler, becomes hardened, causing the sheet to overheat under it and push down from pressure. In an iron boiler, this has been attended by ruptures. In a steel boiler, the buckles of this form can become very deep, becoming thinner at the lowest point until a small hole creates a leak. I have never known an accident to happen from a bulge in a steel boiler, where the boilers could not at once be taken off when the bulge was first discovered. They have been carefully watched until they came down to a depth of six inches before the leak was noticed. The defect is then usually repaired by putting on a new half rim or patching.

A less serious defect, but one frequently found, is in the laps exposed to the greatest heat or directly over the fire; these are cracks extending from the edge of sheet to the rivet hole. This is too often attributed to the double thickness of metal. My experience has been that, in the majority of cases, it is due to the holes not coming fair, causing defective riveting; and again, by the rims, when they are put together at the shop not fitting closely, the hammering by heavy sledges to draw them together, or, in other words, peaning of the edge of the plates. If these

cracks are not discovered in time they will extend back of the rivet-holes into the solid plate; the condition then becomes more serious. It is not always advisable to put on a patch, so that the crack is sometimes stopped by drilling a hole at the end of it and putting in a rivet or copper plug.

A very important consideration is the proper condition of what is termed the trimmings of the boiler, including safety-valves, blow-off-pipes, feed-pipes, water gauges, water columns, with their necessary valve fittings. I can say with positive knowledge that this work is too often carelessly done.

Of boiler losses coming directly to my notice in the past four years, every one, with a single exception, has been caused by the bursting of pipes or the blowing out of same where they were connected to the boilers. While not doing much property damage these accidents usually result in scalding those in the vicinity.

DISCUSSION.

John I. Codman.—There are two points in connection with this subject that should come under the inspector's work. First, is the evaporative power, or, as commonly expressed, the horse-power of the boiler. This is often stated at figures which can only be attained under the most favorable conditions, and to get the promised results it is necessary to fire the boiler beyond the limits of safety. The second is the grossly exaggerated results claimed in evaporating efficiency. I shall only discuss the latter condition this evening.

Boiler manufacturers, to meet the close competition of the present day and impress strongly upon the mind of the purchaser the many merits of their several forms of steam-generators, often publish some remarkable evaporative tests. The principal aim of these tests is to show how many pounds of water can be evaporated from and at 212° F. per pound of combustible. Nothing else is given so large a place in the relative merits of the generator as this item. Nothing is often mentioned about the methods of firing or the skill of the fireman, the suitability of the generator for absorbing the products of combustion or its adaptability for the complete combustion of the kind of coal used

to produce the best results. It is a known fact that certain forms of steam-generators are particularly popular in some sections, and new forms and designs make no headway. These are not mere matters of chance, but result from the hard facts of practical experience. When investigating the merits of a boiler plant the purchaser is visited by agents from the various manufacturers and the great evaporating results of the several generators are impressed upon his mind by the display of a number of tests in which the pounds of water, the pounds of combustible, are so persistently pounded into him, together with dry steam, water tubes and steel shells, that he is at a loss to know what he is buying.

I desire to call your attention to some of the remarkable tests published in a pamphlet or catalogue which I have with me.

This boiler, it is stated, will evaporate from 11.08 to 12.96 pounds of water for each pound of coal. There is no deduction made; it is simply a plain statement— 11.08 to 12.96 pounds of water per pound of coal consumed. In this pamphlet eight tests are given, varying from 11.98 to 14.66 pounds of water evaporated from and at 212° F. per pound of combustible, one of which is stated as follows: time of test, ten (10) hours; kind of fuel, anthracite egg-coal; pounds of water evaporated from and at 212° F. per pound of coal, 12.756; pounds of water evaporated from and at 212° F. per pound of combustible, 14.66. The total heat in one pound of anthracite coal, reduced to fuel free from ash, is given as 14,509 B. T. U. The total heat contained in one pound of water at 212° F. is 965.8 B. T. U. Dividing the 14.506 by 965.8, we obtain 15.02 pounds, which is only 0.36 pounds more than is given in the catalogue. The test of boilers at the Centennial Exhibition in 1876 show that not quite 80 per cent. of the heat in the coal was found in the steam. The figures given are absurd, and tend to discredit boiler-tests that are correct.

There is one thing more. I would like to call, if I have time, your attention to a boiler-test that has been criticised as an incorrect result. The results were obtained by three different trials of the boiler. Objection was made to the amount of unconsumed carbon remaining in the waste-product and deducted from the total amount of coal weighed, and the remainder estimated

as pounds of combustible, from which the boiler duty was computed.

I wish to say that, with some designs of boilers and certain grades of coal, this can be done to a limited extent, and the results obtained are a gain in power and evaporation; in other words, you reject a part of the carbon in the coal, and obtain results that are profitable. I will put the figures upon the board, as shown by the different tests. The first trial of the boiler was a ten-hour trial; the coal burned, 6,026 pounds; waste, 23 per cent.; draught, $\frac{3}{4}$ of an inch of water; pounds evaporated from and at 212° F. per pound of combustible, 10.04; horse-power developed, 135; cleaned fires twice during the test.

On the second trial, ten hours: coal burned, 6,433; draught, $\frac{7}{8}$ of an inch; water evaporated per pound of combustible was 10.62; the horse-power was increased to 144; the waste in that case was 24.6 per cent.; cleaned fires three times during the test.

The third trial with coal burned, 7,023 pounds; draught increased to $1\frac{5}{8}$ of an inch; waste, 32 per cent.; pounds evaporated per pound of combustible, 11.91; horse-power developed, 164; fires cleaned four times during the run, that is, every 2.5 hours; time consumed in cleaning fires was 2 minutes.

The coal used was Schuylkill pea-coal, a good selected class of coal. In the analysis of that coal there was 15 per cent. ash and 5 per cent. of water, $\frac{1}{2}$ of 1 per cent. sulphur, 9.50 per cent. volatile matter, 70 per cent. fixed carbon, making 100 per cent.

The 15 per cent. ash and 5 per cent. of water, making 20 per cent. which contained no heat, are taken from the 100 per cent., leaving 80 per cent. of combustible, of which the fixed carbon is equal to 87.5 per cent., and the volatile matter, 10 per cent.

There are 15,660 heat units in the carbon; 20 per cent. of that is taken out for waste and water; 87.5 of the remainder is 10,962 heat units remaining in the carbon, from which is also to be deducted the heat units wasted in the third trial in the rejected carbon, amounting to 822, leaving 101,40 heat units. The volatile products, I find to contain 21,700 heat units per pound, 10 per cent. of which is 2170, added to the 10,140 = 12,310, as the total heat units available per pound of coal, or, reduced to fuel free from ash, 15,400 heat units, to evaporate 11.91 pounds of water from

and at 212° F. The gain in evaporation over the first trial was 187 pounds of water, or 18 per cent. The gain in horse-power was 29, or 21 per cent.

JAMES CHRISTIE.—Are we to understand from Mr. Hartley's remarks, that he favors the water-tube boiler for marine service? Are there ships now using the water-tube boiler to manifest advantage?

There is one reason why boilers may sometimes generate steam more economically, under the conditions described by Mr. Codman. That is when the rate of combustion is relatively slow—or the grate surface unduly large in proportion to the evaporating surface—there is usually an excessive quantity of air passing through the grate, in some cases nearly double the amount actually required to maintain complete combustion. On the contrary, with more rapid combustion, and a proper ratio of grate to heating surface, the quantity of unused air passing with the burnt products is considerably reduced.

This, however, is not always true, as I know of instances where more water was evaporated per unit of fuel consumed, when the boiler was working at half its nominal capacity, than when at full capacity. I desire to commend Mr. Hartley's illustration of a good method of boiler setting. The boiler should be suspended so as to be relieved as much as possible of local strains resulting from improper methods of suspension.

It should also be supported on rigid iron framing, independent of the brick-work, the latter forming merely a casing but not a support. The method of inserting the feed-water is an important consideration, especially with impure water. The water should discharge at a point that will favor the final settlement of deposit close to the blow-off, and coolest part of the boiler. I know of cases where a simple change in the feed pipe changed the largest deposit from the front to the rear end of the boiler shell.

HENRY LEFFMANN.—In reference to the question just raised I wish to state that certain materials common in natural waters become insoluble when the water is heated, even though there is no evaporation; thus many of the carbonates are held in solution by the presence of carbonic acid, and when this passes off by the action of the heat excess of these carbonates are deposited.

Other salts are less soluble in hot than in cold water; thus it is usually stated in the text-books that calcium sulphate (sulphate of lime) is insoluble in very hot water. Slaked lime is less soluble in hot than in cold water, and clear lime-water will become milky on heating. The formation of scale, therefore, is independent of evaporation, although, of course, evaporation increases the deposit.

I would also like to call attention to the fact that there may be marked corrosion without the presence of any acid in the water except carbonic acid. Very pure waters may be markedly corrosive; air for instance, that is, oxygen, is always present in solution in natural waters, and may cause corrosion at the point at which the cold water enters the boiler. This seems to be specially true when the amount of mineral matter in the water is such as to form very little deposit; a distinct deposit will, in a measure, protect the iron.

Some years ago considerable trouble was experienced in the locomotive boilers of one of the large trunk lines. Dr. Wm. Beam, who was chief chemist of the road, found that the corrosion was produced by some of the purest waters supplied on the line. The same effect is noticed with regard to lead pipes; very pure waters are more dangerous, as a rule, than waters which abound in mineral matter, as the latter coat the lead pipes with an insoluble deposit.

I wish to refer to a point which has merely incidental relation to this matter under discussion, and that is, that in the February number of *Cassier's Magazine* will be found an account of some Pompeian boilers for culinary purposes, constructed on the water-tube system.

Mr. Hartley, replying to questions asked during the discussion said:—In reference to the question as to where the feed-pipe should enter the boiler, I will say that I do not think this materially affects the collection of loose scale and sediment in the boiler directly over the grates, as that is caused by the circulation of the water in the boiler. It is important that the feed-water should be discharged into the coolest place in the boiler. If the water be discharged directly over the tubes at the rear end, it will precipitate the scale-forming matter and constitute

what is termed mud-scale. I believe the feed-pipe should enter through the front head, extend back about two-thirds the length of the boiler, and be turned down so that the water will discharge in the body of water under the tubes in the vicinity of the blow-off-pipe. I do not think the circulation of the water in the boiler will take the scale off the tubes. In the vicinity of Pittsburgh, a number of manufacturing establishments use inside the boiler a goose-neck arrangement which discharges the water into a steam space. I did not approve of this method; in every instance it meant a heavy coating of scale on the tubes directly under the discharge.

I know of a number of ships fitted with water-tube boilers. I understand the U. S. cruiser "Chicago" is now being fitted with them. The ocean steamship "Grand Duchess," recently completed for the Plant Line of New York, is equipped with water-tube boilers; their adoption in preference to the Scotch type has saved 300 tons in weight. They are somewhat similar to the Heine boilers; the only difference is in the arrangement of the steam drums. In the Heine boilers the drums run parallel with the tubes.

III.

STEEL AS VIEWED BY THE ENGINEER.

By P. Kreuzpointner, Altoona, Pa.

Read, February 20, 1897.

If I understand rightly I am to offer three propositions for your discussion and consideration.

First. What kind of steel does the engineer want?

Second. Having decided on a given kind, in what condition should the steel be for maximum serviceableness?

Third. Which are the most approved means and methods to determine the proper quality of a given grade of steel intended for a given purpose?

Steel being an alloy of iron and other elements, chief of which is carbon, then, according to the percentage of these elements present, steel is harder or softer, ductile, tough or brittle. These qualities are produced by the nature of the individual crystals, which go to make up the structure of steel in its compact mass. Thus then, it is the behavior of each individual crystal, supposed to be composed of an unknown quantity of infinitely small particles or molecules, which, in the aggregate, by virtue of their numbers, produce what we conveniently call the properties of steel, and since these properties vary in degree, but not in kind, according to chemical composition and mechanical treatment, one kind of steel is better qualified for a certain purpose than another kind, and thus different qualities are established.

Hence we distinguish between the qualities of dead soft, soft, middling hard, and hard, although these different qualities or grades have the same properties.

Quality then in steel is a function of properties of greater or less intensity, produced or induced by the combined physical behavior, or action and reaction, of the molecules forming the individual crystals. It is well to bear this distinction in our minds because, when we come to determine the methods to ascertain the quality, or suitableness, of a given grade of steel for a given purpose, or ascertain the cause of a certain defect, it is

INFLUENCE OF CARBON ON IRON.
PROF. J. O. ARNOLD.

No. 1. Steel Normal.

No. 2. Steel Normal.

No. 3. Steel Normal.

No. 4. Steel Normal.

often found that the study of the configuration and grouping of the crystals of steel is essential to the formation of a conclusion. Steel, however, is not made up of crystals entirely. There is a softer, amorphous mass of carbonized iron of indefinable character and varying proportions, so that we really have a mass of crystals embedded in a matrix, as Osmond calls it, of softer material.

Osmond, Martens, Sorby, Wedding, Arnold and others claim that there are four or five different substances, forming the mass of steel.

However, for our purpose here to-night we assume two main elements and will not attempt an explanation of Perlite, Ferrite, Martensite, Sorbite and Cementite.

In these sketches, which are copies from a paper read by Prof. J. O. Arnold, of Sheffield, on the "Influence of Carbon on Iron," we can see how the crystalline portion of steel increases with increase of carbon, until it reaches the saturation point with about 0.9 of carbon, according to Prof. Arnold.

The black portions represent the harder crystals, while the white indicate the proportion of softer matrix. It is clear that, as the harder crystalline portion increases, the steel increases in strength and proportionately loses in ductility. It is practically more plainly and comprehensively illustrated in this piece of steel here, which was heated to nearly the fusing point at one end, and at the other end it represents the natural steel. In this piece, not more than an inch, you will notice on one side the crystalline structure, and on the other end it is becoming entirely amorphous, showing in how short a space the structure of steel changes. Here you have the amorphous structure on one end and the granular structure on the other. You will see, moreover, the effect on the structure in breaking off the piece. It was nicked first all around, and broken cold.

And let me right here call your attention to a very common error, one that seems to be gaining ground among engineers; namely, to screw up the requirements for elongations in harder materials. Just as a race-horse cannot be made to do the work of a draft-horse, nor the draft-horse that of the race-horse, so can we not expect the higher strength of the harder steel and the greater ductility of the softer steel to go together. Not only is the proportion of stiffening material greater as the steel increases in strength, but the individual crystals themselves will be harder in a sound, good piece of steel.

Hence, if the engineer tries to circumvent the laws of nature in this respect in his specification he simply invites the steelmaker to exercise his ingenuity how to furnish him a second-class material for a first-class price. What the engineer wants is a metal of sufficient strength to do the work intended; of sufficient ductility to sustain either innumerable small bends or stretches, without distress, or a small number of maximum bends or stretchings, but above all, the engineer wants a sufficiently high elastic limit to guard his structure from being carried beyond it at any time, because straining a structure beyond the elastic limit means a new grouping, a new configuration of the crystals, in fact new conditions in the structure of the steel of a kind for which the engineer originally has not calculated nor bargained.

In short, with the passing of the elastic limit and the establishment of a permanent set, without a corresponding modification

of the stresses, the element of chance begins to take a leading part in determining the further safety of a structure, and this element of chance increases in proportion as our methods of testing, or our knowledge of the properties of steel, are defective.

Having decided on the grade of steel, it is by no means a matter of indifference in what condition the engineer receives the steel for which he has contracted. Steel, like any other kind of material, may be good, bad or indifferent.

Permit me to quote a portion of my contribution to the discussion of Mr. P. A. Hadfield's paper on "Alloys of Iron and Chromium," which he read before the Iron and Steel Institute of Great Britain, at the Spring meeting of 1892, and which he very kindly invited me to discuss. I said:

Three essential conditions determine the fitness of steel for a given purpose.

First. Freedom from oxides, slag, blowholes or any defects which tend to impair the continuity of the structure, and consequently that most intimate adhesion of the individual particles or crystals which imparts to a metal maximum resistance to rupture.

Second. The degree of difference existing in the nature of the two bodies, which, as is now recognized by the highest authorities on physical metallurgy, make up the mass of steel, the crystalline and harder portion and the amorphous or softer portion; this degree of difference in hardness, or softness of the respective bodies, and the predominance of one over the other, determining the "wear and tear" of steel to a great extent.

Third. The hardness or softness of the individual particles of steel; the degree of hardness determining the greater or less resistance of each individual particle or crystal to crushing of change of form, through the stresses applied.

The evil effects of blowholes, oxides and foreign matter in steel are so well known that nothing need be said here.

Of the second condition named, the relative differences of hardness, or softness of the two bodies forming the steel—we have as yet no tangible measure wherein this difference consists, though that there is a difference we can see plainly on the creased and marred surfaces of a polished test-piece.

That the predominance of the amorphous body, or "matrix"

or vice versa, has a good deal to do with the behavior of steel, even the superficial observer will admit.

The crystals, their hardness and number, determine the strength of steel, and if they are wanting we have a metal of low strength, inferior elasticity and high ductility; the metal will set and flow easily under stress. On the other hand, if the hardness of the matrix approaches that of the crystals, without, however, assuming the character of the latter, then we have a stiffer metal with still good ductility. In this case the crystalline portion of steel, in its efforts to resist rupture, receives greater support from the matrix with a resulting higher resilience and "staying quality" of the steel. When the matrix is very soft there appears to be maximum local contraction; when the matrix is harder there appears to be more uniform stretching all over the body of the metal with the same ultimate strength and total elongation. Carrying this analogy to the extreme, we may imagine steel to be entirely devoid of crystals and all amorphous, or matrix, yet possessing greatest hardness, giving the porcelain fracture of tungsten steel, and having a fair degree of ductility.

Now, let me attempt to explain the third condition named above. Often we find two pieces of steel of the same class, having the same, or nearly the same, ultimate strength and elongation, to be structurally different. If nothing else, the surface of the test-piece, after rupture, indicates such a difference.

The surface of one test-piece may appear creased, while the other has a velvety appearance. The fractured surfaces also show a difference. In one case, the crystals evidently were crushed by the stress applied; in the other case, they were not. If both the crystals and matrix are soft and easily crushed, but the matrix is comparatively hard, we have a steel of fair ultimate strength but inferior elasticity. If the crystals are hard and large, and the matrix soft, we have a metal of good elasticity, provided the crystals are numerous enough, the strength will be high, elongation fair, and contraction of area disappointing to those who pin their faith on this deceptive quality measure.

If both crystals and matrix are too hard, we have a brittle metal that may show up all right in tensile and bending test, but will, nevertheless, give bad service because of the liability to

cracking. If the crystals are very small and hard, and the matrix middling hard, we have a metal of superior quality and serviceableness.

You may call this mere speculation, if you please, and in a measure it is speculation, because of our inability to produce quantitative, and tangible proof for the conditions described; but, before you denounce it all as worthless speculation, you will have to deny certain every-day facts, which may be and are observed by those who have the opportunity to test and examine large masses of steel of various grades from various makers, or made by the same maker at different times, when new, and the same metal, when old, broken and worn out. Much can be learned, many of the so-called mysteries of steel can be plausibly explained, if not proven, if we are able to follow a piece of steel from the cradle to the grave; if we can make close connection, as it were, with the train of evidence and phenomena going in another direction.

However, the engineer not only wants a steel of the favorable conditions described; of high primitive, that is, natural elasticity, fair strength and elongation, uniformity of structure, physically as well as chemically, that is, the chemical elements uniformly distributed, and the individual particles of uniform hardness, size, and stress resisting configuration; he not only wants maximum cohesion between the particles, but he also wants the structure of the steel free from internal stresses.

Probably, a good many cases of so-called mysterious failures are due to the internal stresses, or, as Mr. H. K. Landis calls them, residual stresses, remaining in the steel from improper treatment.

The researches of James Howard, of the Watertown Arsenal, of Martens, Chernoff, Bauschinger, and others, have not only experimentally proved the presence of such stresses, but the great school of experience and that invaluable teacher, comparative knowledge, give us ample evidence from time to time of the injurious presence of internal stresses.

The sudden and unexpected cracking of iron and steel casting without apparent cause, is quite well known, and understood to be due to shrinkage and molecular changes in the metal.

Not so well known, nor so easily demonstrable, is this phenomenon in rolled and hammered material, because masked by other complex conditions.

How can we tell of the presence of internal stresses? I know of no means to detect them in finished material before it goes into service, although an experienced person can see by the way steel is treated in the mill or shop whether internal stresses will be developed or not. Some years ago in a beam mill the flanges of an I-beam were slotted off and the web shrunk one-eighth of an inch in its total length when freed from the restraining influences of the flanges.

Whenever we find radial lines, beginning at the surface or periphery of a fractured structural material, and running toward the center, gradually thinning out into nothing, we may be sure that internal stresses had a good deal to do with the premature fracture of such material.

These injurious stresses are chiefly due to changes of structure due again to unequal heating, which tends to produce groups of particles of varying density, the cohesive force in one or more groups being different from all other groups, each group being under strain to establish an equilibrium with the neighboring group or groups.

It is not difficult to comprehend the origin of these internal stresses when we know, as we do to-day, thanks to the researches of Osmond, that steel is in a period of transition when heated, up to the critical point, which is that point where the structure of the steel changes quite rapidly from one form to another. This critical point varies with the carbon contents and completes its course within a definite number of degrees of heat.

Having thus briefly offered some debatable points as regards quality of structural steel, let us now open the gate to that large and fertile field for discussion about the methods of testing and inspection. Why do we test and inspect? To prevent accidents to our fellow-beings and to avoid the heavy expense of replacement of structures, or part of structures, due to excessive wear and tear, or breakdowns.

In other words, economic conditions compel the engineer to avoid preventable waste of our natural resources and accumu-

lated capital. Wasteful use of resources or capital means their destruction without useful application. The logical conclusion, then, is that testing and inspecting are important factors in the household economy of the nation, and, therefore, the methods of doing so deserve our closest attention and a liberal expenditure of money. The cheapening of an article of commerce by a small amount of money may be, and often is, the difference between the purchasing power of large numbers of people who could not have bought the article before it was cheapened. Likewise, if accumulated or borrowed capital has to be applied to pay for preventable waste, that amount of resources or capital is withdrawn from the development of our industries or cheapening of transportation, with consequent expansion of trade and commerce. A manufacturer may rejoice to get a large order to replace wornout or broken material, but if the money necessary to pay for that material represents preventable waste, it may mean the curtailment of other, larger purchases, that would have been necessary, if that money represented the difference in the increased purchasing power of the people, due to a cheapening of products or transportation in a certain direction. Hence, the economic value of testing and inspecting and the increasing necessity to base the methods of doing this work on scientific principles; although in commercial testing we must be satisfied with an approximation to scientific accuracy.

The engineer must be able to interpret properly and quickly the phenomenon produced by mixing certain percentages of chemical elements in the furnace, and the effect of mechanical treatment in finishing the resulting product, but while we can determine the amount of specified chemical elements on the chemist's balances in the finished product, this is not quite possible in regard to the physical properties of steel, and just because our present state of knowledge of the physical properties of iron and steel is only an approximation, though perhaps a close one, we ought not to be satisfied with crude methods in determining the qualities of a given grade of steel for a given purpose.

The criterion of the economic value and success of methods of testing and inspecting steel is the ability of the engineer to adopt

such means and methods as will enable him to determine as quickly and nearly as possible the value of that particular quality of the steel he intends to use, which will have to do the most work in his structure.

Let me illustrate. Here are two pieces of iron bent double under the steam-hammer. A test like this, for iron, has always been accepted as an indication of good quality. Yet it is not. Valuable as a test like this is, it does not show all the engineer wishes to know, and ought to know, about the qualities of the material he uses. It may be surprising to know that one of these pieces is very poor. This is but one instance where the progressive, up-to-date engineer has to discard old, accepted notions, and extend his inquiries into other directions.

I will presently come back to this test, but, in passing, let me say that, while this test is not an indication of good quality in iron, this same test is a very good measure of ductility in steel. Why? I will explain later.

Again, supposing I am told that two lots of material, say iron, are equally good, because samples out of both lots may be bent back and forth at will, without either of them breaking below a given number of bendings.

I have here a strip of pasteboard and a strip of sheet-iron. Both can be bent back and forth a great number of times, the pasteboard even easier than the iron. But because of this, is any one willing to say the pasteboard is as strong as the iron? It may be, as far as bending is concerned; but when I begin to apply torsional stresses, the pasteboard can be easily torn with the fingers, but not the iron.

Thus, one of the two lots of iron, or axles, or shafts, may be unable to stand many torsional stresses, notwithstanding its adaptability to bending. Why this should be so, is another question entirely. It is simply an illustration of the necessity for the engineer to adopt the right means to attain the right end.

Etching, and the study of the micro-structure of steel, is becoming more and more a most valuable auxiliary to enable the engineer to judge about the quality of a material, though this method of testing has not yet been developed sufficiently to base quantitative conclusions on it, similar as we get in other methods

of testing. In etching iron, however, we do not need the microscope to be able to say which of the pieces lying before us is preferable. Judgment based on experience and comparison, is also a very valuable friend, not only of the engineer, but also of the manufacturer. It is the engineer who observes the behavior of steel in service, and therefore is, or should be, able to give the manufacturer valuable information as to the influences of certain methods of manufacture on the final quality of his product. In this way very satisfactory results may be obtained, and a good deal of friction and misunderstanding avoided. Considering the quantitative determination of the qualities of steel for a given purpose by tensile testing, drop testing, nicking, bending, crushing, and twisting, it is well to bear in mind that, while we cannot possibly go into elaborate details in every-day commercial testing, we yet ought to aim at a tolerable degree of accuracy.

The further we depart from a given ideal standard we have in our minds, the more we lose control of the aim we are pursuing and lose the bearings set for our guidance by exact science.

Elasticity, stretch, strength and contraction of area are the elements constituting a tensile test. Let us consider, first, elasticity. What is it and how does it manifest itself?

Steel is a viscous solid, composed of an innumerable number of particles or crystals, each individual crystal a body of itself with characteristics of its own, these crystals cemented together by their sides with a matrix of softer material than the crystals and of different chemical composition. Hammering and rolling breaks up the large crystals as they exist in the ingot, condenses the whole mass, breaks up original groups of crystals and forms new ones in conjunction with the heat necessary to work the metal. The last stage of heat or work, or both combined, determines largely the suitability of steel for the work it has to perform. Thus, quality is a complex function of the last stages of heat and pressure.

Now then, in trying to picture to our minds what takes place in a piece of steel when we strain it, we have to bear in mind the dual condition existing in the steel by virtue of the degree of hardness of each individual crystal, and the degree of cohesion with which these crystals are held together by their sides, each of

these conditions intensified or moderated according to the amount of work or degree of heat to which the metal was subjected.

Barnes, in his "Viscosity of Solids," says in regard to the viscosity of steel: "The relations between hardness and viscosity here encountered may perhaps be conceived somewhat as follows: Suppose stress to be so distributed in a solid that its application at any interface is nowhere sufficient to produce rupture. Then that property of a solid in virtue of which it resists very small forces (zero forces), acting through very great intervals of time, may be termed the viscosity of the solid. That property in virtue of which it resists the action of very large forces acting through zero time may be termed the hardness of the solid. Since the application of forces in such a way as accurately to meet either of these cases is rare, we have in most cases a mixture of viscous resistance and hardness to encounter. We may reasonably conceive that in the case of viscous motion the molecules slide into each other, or even partly through each other, by interchange of atoms, so that the molecular configuration is continually reconstructed; that in the other case (hardness) the molecules are urged over and across each other, and that therefore the intensity of cohesion is in this case more or less impaired. In most cases of scratching (indentation of the surface) the action is indeed accompanied by physical discontinuity of the parts tangentially strained." Now, if we accept this explanation as plausible—and every-day experience as well as the study of the microstructure of steel make it plausible—we may conceive the elasticity of steel as a complex function of both the degree of hardness of the crystals and the degree of cohesive force with which the crystals are held together.

The first application of a small stress sets the molecules into motion, of which the individual crystals are composed, without disturbing the cohesion of the crystals. As stress increases, the cohesive force is overcome and the crystals as a whole begin to slide upon and over each other. If we stop straining the structure before the sliding of the crystals itself begins, then the activity of the molecules produces elastic reaction, and in virtue of this reaction the metal assumes its original form. If, however, sliding of the crystals has begun, then permanent set takes place, and this

set will be the greater the further the crystals have been separated and torn away from the original position they occupied before being strained. It is conceivable that at the same time as sliding begins the shape of the crystals is altered, according to the pressure exerted and the degree of hardness of the crystals itself. But even in that case the viscosity of solids asserts itself and sets up a still more violent elastic reaction, which has been observed to last for days and weeks, restoring partly, but never entirely, the original form or dimension of the metal. Maxwell explains elastic reaction as a difference of the state existing in different groups of molecules. "In this case," he says, speaking of permanent set, "some of the less stable groups have been broken up and assumed new configurations. But it is quite possible that others, more stable, may still retain their original configuration, so that the form of the body is determined by the equilibrium between these two sets of groups; but, if, on account of rise of temperature, violent vibrations or any other cause, the breaking up of these less stable groups is facilitated, the more stable groups may again assert their sway, and tend to restore the body to the shape it had before deformation."

We can easily comprehend from the foregoing what a multitude of conditions may influence the degree of elasticity of a piece of steel according to even very small variations of chemical elements or mechanical treatment or degree of heat in finishing. We can also comprehend why small crystals, imbedded in not too hard a matrix, as described in my discussion of Mr. Hadfield's paper, give greatest strength and elasticity, other things being equal, because not only does the greater number of sides, coexisting with a greater number of crystals in a given space, give greater density and resistance to sliding of the crystals, but the smallness of the crystals favors uniformity in the character of each individual crystal, less difference in the instability of groups, if it exists at any time, a more favorable field for elastic reaction to complete its activity.

We also may perceive from this why opposing stresses, like tension and torsion, tension and compression, tension, shock and torsion, are more detrimental than simple stresses acting only in one direction. The stress has just set viscous action of the

molecules in motion, and the cohesion of the crystals is being forced to exert itself to resist sliding, when all at once an opposite stress intervenes and forces the action out of line into new conditions, thus creating disorder and confusion, loss of the grip, as it were, the forces had already obtained on the material. Something like a choppy sea, where a second wave breaks up the first one before it had time to complete its course.

Thus again, putting all the available theoretical and practical evidences together, we perceive how that phenomenon in steel, which we call its elasticity, is a complex function of intermolecular activity and cohesive force which act and react upon each other on the application of stress, the intensity of such action and reaction depending not only on the degree of intensity of stress, but on the physical nature of the crystals and their configurations according to the last stages of heat and pressure in finishing and the degree of uniformity of distribution of the chemical elements.

This complexity of circumstances seems to explain to us some of the vagaries we encounter when we attempt to determine the degree of elasticity in steel—where it begins and where it ends. We can readily perceive how in one case intermolecular action, producing viscosity or elastic reaction, is greater than the cohesive force preventing the crystals from sliding out of their position, due perhaps to a greater hardness of the matrix, while in another case the cohesive force is inferior to viscous action, and permanent set takes place notwithstanding the efforts of the more stable groups, which react violently to establish an equilibrium.

It explains to us also why the engineer deceives himself when he bases his calculations on that fictitious value, the elastic limit as obtained by the drop of the beam.

Bauschinger was the first to show, and others have proved it since, that there is no elastic limit proper in steel; that at any and every stress a set takes place. However, that set is so small that it has no influence whatever on the practical work of the engineer.

These sets, however, begin to become a matter of consequence when the limit of proportionality is reached. We may perceive

the elasticity within the limit of proportionality to be the beginning of viscuous activity and a tightening up, as it were, of cohesive forces holding the crystals together, the latter action producing minimum set, while the former disappears speedily after stress is removed.

At the limit of proportionality sliding begins in earnest and the elastic reaction becomes very active.

At the third stage, where there is an interval of stretch without increase of load, indicated by the drop of the beam, the crystals are leaving their original positions and tumble over each other until they become locked and hooked into each other again, and the length of time necessary to accomplish this indicates then the length of the period of stretch without increase of load. Hence, at that point when the beam drops the original configuration of the crystals and the molecules forming the crystals have been broken up and we have an unstable mass of particles violently agitated, trying to find new positions, to form new groups and configurations, while the elastic reaction is doing its best to bring some kind of a stability into the unstable mass after days and weeks of efforts.

Therefore, at the drop of the beam the engineer deals with a metal in a highly unstable, highly agitated condition, remaining unstable the longer the further he is away from the primitive elastic limit, the metal remaining in a condition entirely beyond the calculation of the engineer, and is, therefore, a matter of chance. We can form new elastic limits to near the breaking point of the metal, because with every stress and rest the phenomenon of breaking up of groups, of new sliding, of new attempt to support each other, and of viscuous action is repeated to the last.

"I might explain this action in a crude way with this spring (shows a brass wire spring about 12 inches long). If we compress the spring some and release the compressive force we may conceive this to be the limit of elasticity. If we compress the spring solid and release an insignificant set has taken place and we have reached the limit of proportionality. Compressing the spring still further it loses its shape, twists and bulges out. This stage is equivalent to the stage the steel is in when the elastic

limit is taken at the drop of the beam. To be sure, we have still a good deal of resistance and springiness in the spring at that stage, but it certainly is not in the shape and condition of a useful and reliable spring any longer."

Incidentally let me mention here that the dissatisfaction of many engineers with soft steel is probably partly due to the higher degree of viscosity or elastic reaction in softer steel, and which appears to last longer in soft steel, due apparently to the greater mobility of the molecules. Thus, the strength-giving particles of the steel are in a constant state of unstableness, of groups breaking up and new ones forming, of a constant tremor that soon fatigues the metal. Because viscosity or elastic reaction decreases as the hardness of steel increases, in duration as well as in intensity, and resistance to sliding seems to be greater, therefore there is logic in the growing preference for a middling hard steel by the engineer. I have thus dwelt at greater length on the phenomenon of the elastic limit, because it is really the criterion of the metal's usefulness and because of my desire to give the reason why I am so strenuously opposed to the drop of the beam being considered a reliable measure of quality.

Here are two etched pieces of iron axles. You will see they are radically different from one another. One is beautifully hammered and the layers of muck bar are very well shaped and show the structure of the axle. The other is a nondescript mass. Supposing we make a drop test of these two axles. Experience shows iron like this to be inferior and unsuitable for iron axles. It may do a certain amount of service, but if I have the preference I would at any time select material like this. (Showing sample.) Then someone says " Why both of these axles stand a number of blows." That may be so. Why should it be so? Here we have some cold short iron mixed with neutral iron and some scrap. If we put that under the drop the first blow will be sustained by the neutral or finer crystallized portion of the iron. As the blows increase the cold short material begins to become fibrous, that is, the work done by the drop is equal to the work done under the steam hammer, drawing out the crystals into fiber. Now under the drop test this axle may stand a good many blows because the coarser crystals under the drop become fibrous. In

other words the material is in such a condition that the blows of the drop will improve it. As the other piece is in a first-class condition when we begin, consequently the drop test of the two axles would not necessarily show that the one is not as good as the other, because the work of the drop changes the structure of one and improves it and makes it better, and thus deceives the person who contends that one axle is as good as the other. (For various reasons this is not an argument though against the drop test.) True, they may say one stands nearly as many blows as the other, but when we come to apply this axle to torsional strains, to the blows and shocks going over frogs and switches, then the structure I now show is clearly not as well adapted as this other beautiful fibrous structure.

In the foregoing neither time as a factor, nor the phenomenon of continued stretching of a test piece, if the load continues to act without increase of the same; nor, also, has that point been considered, What property appears to make steel safer than iron under certain conditions?

It has been proposed to use the maximum load instead of the breaking load as a factor for the engineer's calculations. Thus far, however, the difficulty of getting the exact maximum load has prevented the introduction of this measure.

In regard to elongation as a measure of quality there seems to be a universal agreement at present of its being a more reliable and trustworthy guide to determine ductility, than contraction of area. A piece of steel, stretching uniformly over the whole section, indicates uniformity of structure, and this is a quality about which the engineer is very much concerned. For commercial testing, measuring the total stretch is sufficient. For scientific testing, the French Commission recommends measuring the elongation in different parts of the section separately, and thus distinguish between elongation of contraction and elongation outside the zone of contraction. At Altoona they use these scales for measuring elongation. They are very handy. Say in a 2″ section one half is divided into fifths; all one has to do is to put the point into the punch mark and read off his elongation.

As far as contraction of area as a measure of quality is concerned, it is more and more recognized that its value has been

very much overrated. At best it is only an indication of the local condition of the metal at the point of contraction, and the best proof of its unreliability is the fact that Woehler, who is the father of contraction of area as a measure of quality, has abandoned it himself. Professor Martens, on giving official instructions as to tensile testing to all those doing any testing of railroad and other material, makes the following remarks about contraction of area.*

"Years of experience and very extended investigations have taught the contraction of area an unreliable measure of quality; more so than elongation, and after some resistance on the part of the originator it was abandoned by him and most of those who had used it." If the originator of contraction himself abandons it as erroneous, then we can leave arguing about its value with those who cannot get out of old, time-worn ruts and superstitions.

Drop tests of steel, while not so valuable for iron, are very valuable for steel whenever the intended structure is to be subjected to sudden and intermittent shocks.

Iron and steel flow very easily under pressure. Hence the philosophy of the drop test consists in discovering whether the metal in the intended structure will flow as easily under a sudden blow as under a slow pull. In other words, whether a structure is able to adapt itself quickly to unexpected requirements. Hence the increasing preference of the engineer for the drop test.

Nicking and bending tests are other valuable tests to indicate quality and to supplement the tensile test.

A great deal more could be said about the properties and qualities of steel and methods of testing. However, I have strained your patience already far beyond the yield point, and rather than cause rupture I shall now ask for your kind criticisms of the points presented for better understanding and scientific progress.

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* *Mittheilungen*, Erstes Heft, 1893, p. 33.

DISCUSSION.

THE PRESIDENT.—We have had a very interesting paper from Mr. Kreuzpointner, and we may be benefited further by a discussion on the subject. As we meet informally, it would be well for those most interested to come forward and look at the samples. I understand we have with us Mr. Colby, of the Bethlehem Iron Co., and it would be interesting to have him open the discussion.

MR. ALBERT LADD COLBY (Visitor.)—In accepting your kind invitation to be present this evening, I did not think I would be called upon to make any remarks, for I anticipated that, inasmuch as representatives from the manufacturers had opened the discussion on steel at your December 19th meeting, to-night their papers would be criticised and the only speakers allowed would be the users of steel, the engineers who write the specifications, and the inspectors who pass upon the manufacturers' product; but instead of a reply to the manufacturers' side of the case, including Mr. Campbell's criticism of some points in the specifications under which he is called upon to furnish steel, or Mr. Christie's important suggestion that the usual tensile test required in specifications is an insufficient and often a misleading measure of the capacity of a steel to withstand dynamic stresses, or my claim that the failure of steel is often due to the faulty mechanical treatment it received in the customer's hands, or to the selection of a too low carbon steel for the work demanded of a forging, we have listened to a plea for even more thorough testing and careful inspection of iron and steel than specifications at present require.

From my personal acquaintance with Mr. Kreuzpointner, I am not surprised that he takes this view. He has made a very careful study of the testing of iron and steel, and too modestly refers to the aid that he has given some manufacturers by valuable suggestions as to how their product could be improved. The inspection of material is more necessary to-day than in former years, partly because sharp competition tempts some manufacturers to bid a lower price than one at which they can furnish a good material, and trust to careless inspection for its acceptance, but mainly because steel is now used for a multitude

of purposes where the demands upon it are much more severe than were even dreamt of years ago.

Our customers admit that specifications are more rigid to-day, because their processes are cheapened and the manufacturer's product more roughly handled in consequence. For instance, a 4-inch billet is now drawn to a $\frac{3}{16}$-inch rod at a single heating. Automatic machines geared up to their maximum capacity, are sensitive to the slightest variation in the hardness of the manufacturer's billets. Axles are now rapidly turned in turret-lathes with a cutting tool the full length of the journal, instead of in ordinary lathes with a small traveling tool. If the turnings hang to the cutting edge in the modern turret-lathe, a rough-turned axle results, and the manufacturer's steel is said to be at fault. The specifications of some customers allow entirely too limited a range in chemical composition in the very high carbon open-hearth steels which the customer expects to substitute for crucible steel for a great variety of purposes, and even under these circumstances the manufacturer is expected to replace the occasional billet of this material, which is sold by the ton, because, on account of seams or pipe, this billet cannot be made into the so-called "crucible steel" tools, which are sold by the pound at a good profit.

A reference to the order books of any steel works which has manufactured steel since the seventies, will show how little was demanded of the manufacturer years ago, when his customer's profits were large and rejections never referred to; whereas to-day, with the manufacturer working on even smaller margins than his customer, almost every order is accompanied by chemical and physical specifications, and in some cases a demand is made that the steel shall be guaranteed to give satisfaction for the purpose intended. This latter request is unfair to the manufacturer, for, as I pointed out in one of the papers read at your previous meeting, the failure of the steel is often due to the customer not annealing his manufactured articles, especially those of large sizes, in which the establishment of internal strains is particularly fatal.

As stated before, Mr. Kreuzpointner, representing a large consumer of steel, suggests that the manufacturer's product should

be even more thoroughly tested and inspected. I am willing to meet him half way in this suggestion. A fair increase in the requirements demanded of the manufacturer can be met, for he is to-day materially aided by well-equipped chemical and physical laboratories in maintaining greater uniformity in his product than in former years. There is, however, an important factor in the problem of adjusting the customer's demands to the manufacturer's idea, which Mr. Kreuzpointner has not touched upon; a factor which exercises as great an influence in securing what he wants as his carefully worded specifications, and that is the *price* which his company's purchasing agent is willing to pay for the material. It is manifestly unfair to the manufacturer if the customer's engineer, in presenting a more rigid specification to the purchasing agent, fails to frankly admit that it can only be met by heavier top discards or slower and more careful methods of manufacture, and that they cannot expect to obtain the better article at the price of former lots of inferior material, which have undoubtedly proved in the end to be more expensive purchases, or the engineer would not now be demanding a better article.

No one is more directly interested than a wide-awake manufacturer in the efforts referred to by Mr. Kreuzpointner, which are now being made both abroad and in this country towards a unification in the methods of testing, so that iron and steel will be submitted to tests which will truthfully measure their value for the purposes to which they are to be used, for with such improvement the care exercised in the manufacture of his product will be more clearly appreciated, and his just demand for a higher price more willingly recognized.

THE PRESIDENT.—I suppose there are some other manufacturers here. We have heard the engineers' part of it at some length.

JAMES CHRISTIE.—The Club is indebted to Mr. Kreuzpointner for his interesting paper on the physics of steel. It is a branch of the subject deserving careful study by those who desire to obtain a clear and rational conception of the fundamental properties of the metal. There are so many contradictory statements afloat, that it is well, when searching after facts, to accept the opinions of interested parties *cum grano salis.* An old adage says "men try to believe that which they wish to be true," and it is quite natural for the manufacturer, who may be hedged around

by annoying restrictions, to disagree with the inspector, who, on the other hand, may be seeking the impossible.

If specifications were always governed by the experience and well balanced judgment of those represented by Mr. Kreuzpointner, there would be less occasion for the criticism of Mr. Campbell on this score, during the last discussion.

In a quite recent specification for a certain class of structural steel, the author requires the metal to have not less than $\frac{5}{10}$ per cent. manganese, also that it should be annealed by heating to a certain temperature, and cooled so that 24 hours will elapse before falling to normal temperature. Now it is difficult to understand why the consumer should specify a minimum limit for manganese, or for that matter whether there should be any in the steel. Inspectors frequently complain that the tensile strength of annealed bars is lower than the original test pieces, yet the proposed systems of cooling selects a method that will insure this behavior. I agree with Mr. Kreuzpointner in drawing a marked distinction between elastic limit and yield point. The former being the limit within which stress is proportional to strain, the latter is modified by speed of testing, and also sundry other considerations, consequently there is no fixed ratio between the two, and in some metals the interval between the two is much greater than in other metals.

Mr. F. Schumann.—There is one thing I desire to touch upon from the standpoint of a plain, every-day user of steel for machines and structural purposes. What attracted my attention was the suggestion of a higher grade of steel for such purposes. In our practice we bend and curve to form angles and other shapes. Even beams up to ten inches in depth are bent to angles approaching 45 degrees. A good deal of judgment is required to do this bending and forming properly, especially to prevent the excessive stretching of the outer fibers, which tend to reduce the thickness of the flanges. Similarly, in punching or slotting shapes, such as angles, channels or beams, there is more or less tendency to cracking in the higher grades of steels; consequently, we strongly favor the use of softer grades. When using steel for crank pins that are fastened by riveting the head at the back, which is done cold, we get the best results from soft steels; their use may induce greater wear on the pin, but we meet

this by changing the composition of the bronze in the bearings. While we anneal all steel that has been worked hot, we obtain much better results more readily in soft than in harder steels, and for these reasons the impulse is in favor of soft steels.

MR. CHRISTIE.—Soft steel should not be used for crank pins, or axles, or any service when exposed to severe abrasion; it shows a tendency to cut on little provocation. More especially is this true when the material rubs on similar metal; for this reason it gives poor results in toothed gearing. It has been a frequent occurrence for gearing of soft steel to bé destroyed in a few months, when the same pattern in harder metal endured in a satisfactory manner. For these reasons the steel in heavy gearing should contain not less than 0.5 per cent. carbon—and better if higher.

MR. JOHN BIRKINBINE.—As engineers, we may in our specifications, "protest too much," and thus make our requirements more difficult of execution than conditions warrant. It is questionable whether, unless a man has had the experience of a practical manufacturer, or has gone through the detaii of mill work, he is equipped with such knowledge as to permit him to properly specify all physical properties, and chemical composition of the materials which are to be produced.

Some of the specifications issued for iron and steel present so many difficulties, that they may be justly credited with causing the trouble to which Mr. Colby refers. An instance of this was brought to my attention several years ago when called on to assist a large manufacturing company to estimate for work, in which the specifications for the steel required suggested the recommendation of addressing letters to prominent manufacturers with the idea of learning if the material could be produced, and if so, at what cost. Replies to these queries were that while such steel could be made the material would be very expensive if the specifications as detailed were lived up to, an expense too great for the purpose for which the material was required. These letters were submitted to the officer who had issued the specification and who wrote to the company with which I was associated expressing surprise, and stating he had based his specification on the published statement of results obtained by one of the steel companies who objected to the severity of the present specifications.

The facts of the case were that this steel company had made a special casting which had materially exceeded the requirements as laid down by the specification for the casting, and with business acumen had made known the fact that their work was even better than they had contracted for.

In drawing up the specifications for the work upon which we were estimating the officer in charge had taken the maximum result published by the steel company, and used it as his minimum by specifying that all castings of any heat in which any single specimen fell below this maximum were to be rejected.

We should keep our specifications within the limits of our knowledge, and it is generally safer to permit as much elasticity as will insure obtaining the desired results.

MR. KREUZPOINTNER.—In regard to Mr. Shumann's remarks I beg to say that it is not always the softest grades of steel that are the most ductile and pliable. The maximum portion of the structure of soft steel is matrix, with harder crystals dispersed through the mass in the shape of, roughly speaking, large, open meshes of a very coarse network. Now if the matrix is not in a proper condition it will crack and break in bending, or in service, while in the harder grade, if both the soft matrix and a harder crystalline network are in proper condition, we have greater elasticity, greater hardness and resistance, and yet nearly as good ductility as in the softer grade, and very likely just as much ductility as we want and need. Here is a piece of boiler-steel of 53,000 pounds per square inch and 34 per cent. elongation in 8 inch section; yet it could not stand doubling upon itself and cracked open while these pieces of 56 and 59,000 pounds per square inch and 28 per cent. elongation could be doubled, showing a beautiful velvety surface on the convex side. How to produce such metal is the manufacturer's lookout. That it can be done without increase of cost, but by exercise of proper care and judgment in the mill, seems to be proven by the hundreds of similar cases coming under my observation, with metal of the same price from different makers or from the same maker made at different times.

As to the beneficial effects of proper annealing on steel, of which Mr. Colby speaks, there is nowadays but one opinion as to the great value of this method whenever it is practicable to apply it.

IV.

THE QUEEN LANE DIVISION OF THE WATER WORKS OF PHILADELPHIA.

PART V*.—THE RESERVOIR.

(a) CONSTRUCTION.

By AMASA ELY†, Active Member.

Read March 20, 1897.

Site.—The Queen Lane Reservoir is located midway between the Falls of Schuylkill and Germantown, upon a plateau sloping toward the south, its boundaries being Thirty-third, Queen and Thirty-first Streets and Abbottsford Avenue. (Fig. 1.)

Geological Formation.—Underlying the top soil on this tract are the gneiss rock and mica-schist, so common in and about Philadelphia. Near the surface, these rocks are more or less decomposed. Thus, we have, immediately over the solid rock, the same rock in a partly disintegrated condition, while higher up it has become reduced to a nearly sandy condition, and consists chiefly of mica and quartz. Overlying this, and nearly continuous over the site, is a layer, varying from 18 to 30 inches in thickness, of a sandy clay, and upon this rests the top soil.

Embankments.—The embankments of the reservoir are composed chiefly of the decomposed micaceous rock found upon its site. The outer slopes vary from 1.3: 1 to 1.8: 1 (Fig, 2), while the inner slope is uniformly 1.64: 1. The normal top width of the bank is 18 feet. At the southwest corner, where the carriage way encroaches upon the banks, the top width is reduced to 16 feet, but at all other points it is at least 18 feet. The height of the embankment varies from 17 feet at the northeast corner,

* For Parts I to IV, see Vol. XIII, pages 35, 41, 47, and 245.

† This contribution is the text of a report made by Mr. Ely, in 1895, to Messrs. Rudolph Hering, C. W. Raymond and John C. Trautwine, Jr., experts appointed by Mr. Thomas M. Thompson, Director of the Department of Public Works, to investigate the condition of the reservoir. Mr. Ely's report was published in that of the Bureau of Water for 1895. Mr. Ely's death having prevented his presentation of a paper upon the subject, this report is submitted as the best obtainable substitute.

where the natural surface is highest, to about 40 feet at the northwest corner, where the natural surface is lowest.

Core Wall.—Near the centre of the embankment is a core wall, composed principally of the sandy clay found upon the site of the reservoir.

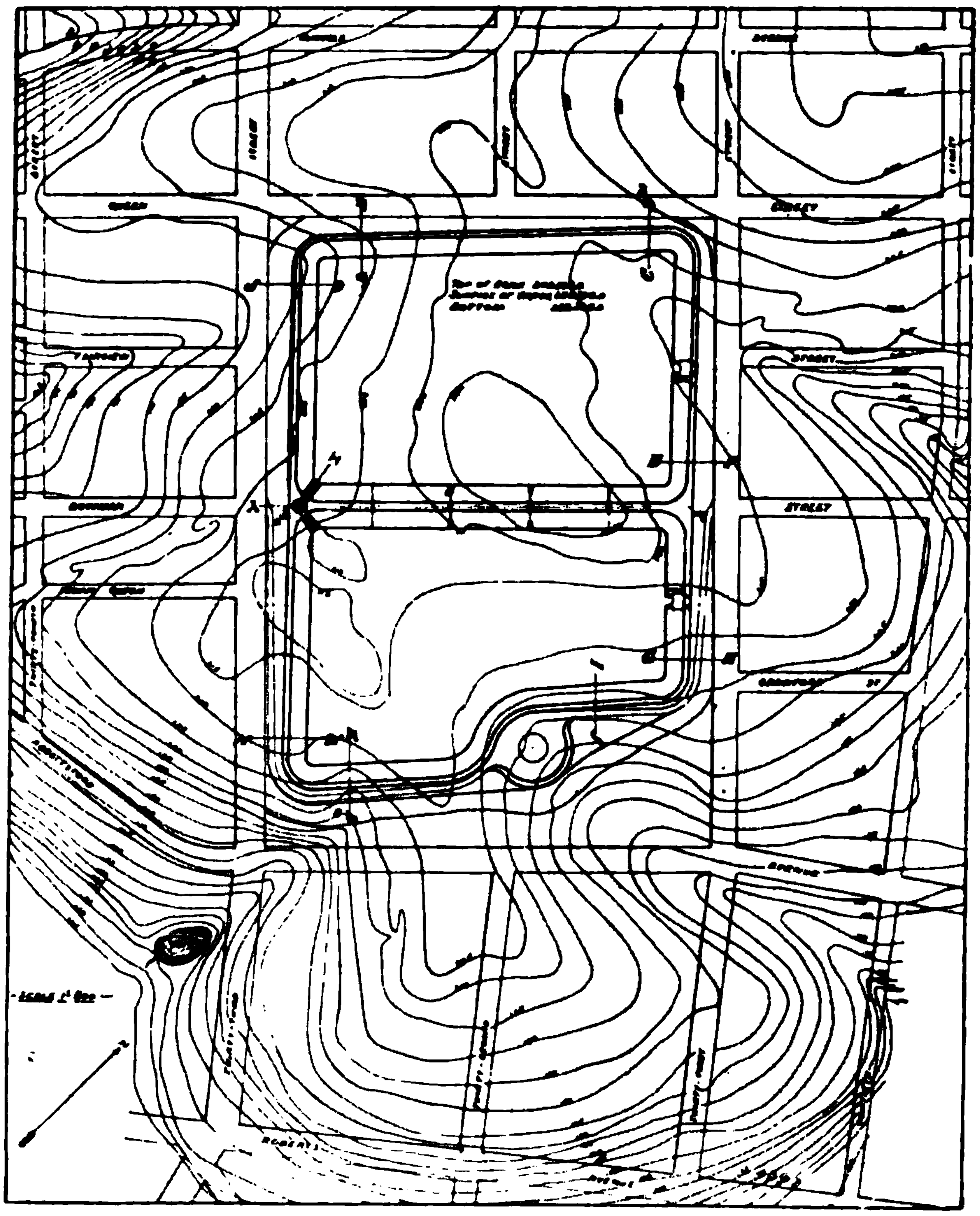


FIG. 1.—TOPOGRAPHICAL PLAN OF RESERVOIR AND VICINITY.

Construction.—Work on the construction of the reservoir was begun October 10, 1892, by stripping off the timber and brush, and removing the top soil. After the removal of the top soil, the puddle trench was dug to a depth of three to five feet, or half the width of the puddle wall at its starting point. The foot of this wall is, in all cases, in the decomposed micaceous rock.

The contractors were authorized to use, in the puddle wall and on the bottom of the bank between the puddle wall and the inner lining (See Fig. 2), the clay found on the reservoir property, and this material was used throughout the entire length of the puddle wall, except across the railroad openings and over the low ground near the north end of the west bank, and east of the southwest corner. At the latter places clay from the outside clay pits was used from the bottom of the puddle wall to about half way up the embankment, above which point clay

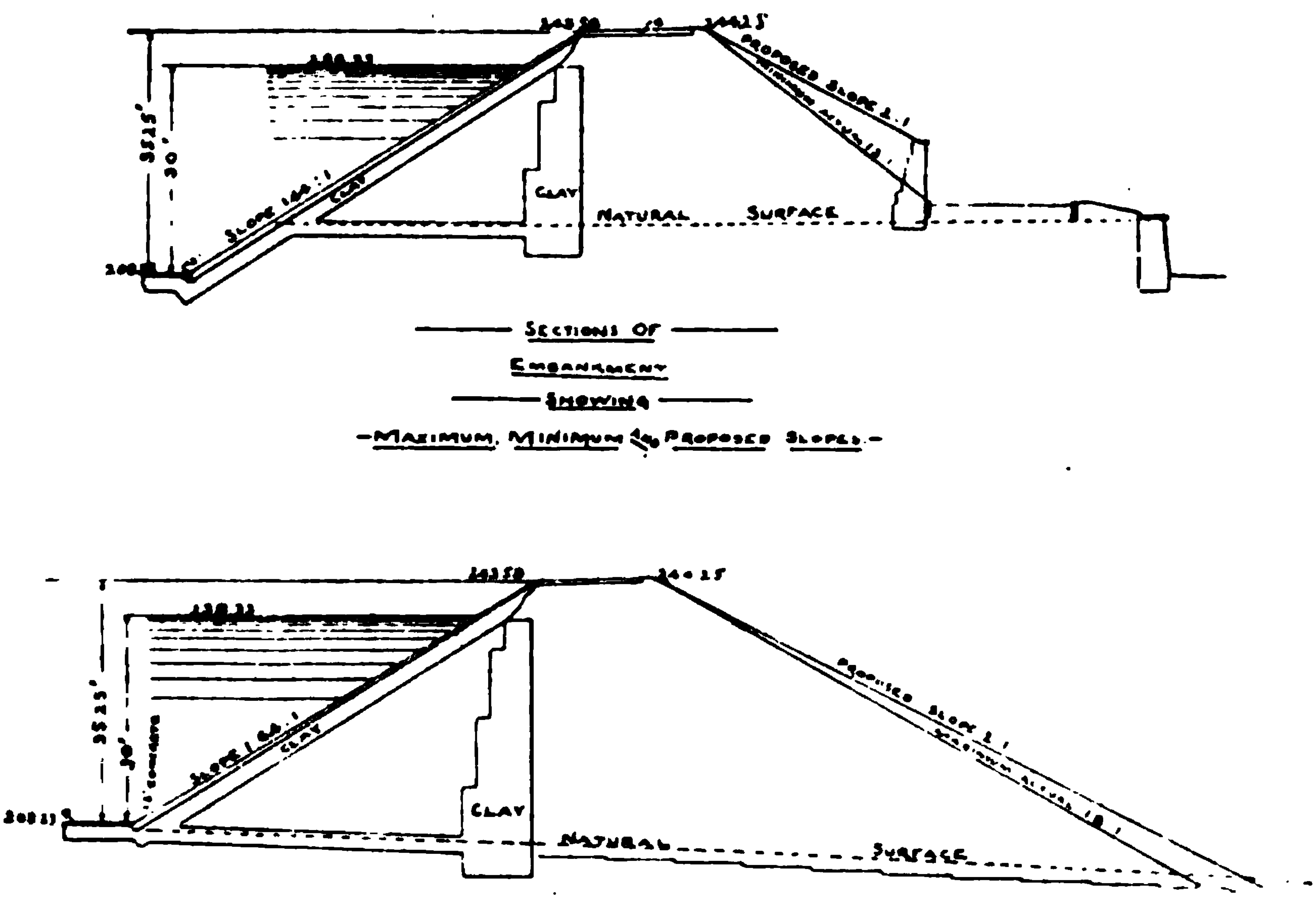


FIG. 2.

from the reservoir ground was used. The entire puddle wall across the railroad openings was built up with clay from the outside pits. The material for the puddle wall was placed and rolled at the same time with that for the banks.

The clay found in place on the site of the bank between the core wall and the inner slopes was broken up with plows and shovels, and afterward rolled and left in place. It was not reinforced with clay from the outside pits.

The top soil was completely stripped from the base of the bank,

and, where the natural surface had a slope toward the outside of the bank, as near the northwest and southwest corners, steps were cut into the original surface to break the slope, as shown in Fig. 2. All around the outside of the embankment, a toe, about 18 inches deep, was cut to receive the foot of the outside bank. Across the low ground already mentioned, this toe was made about 2 feet to 2 feet 6 inches deep.

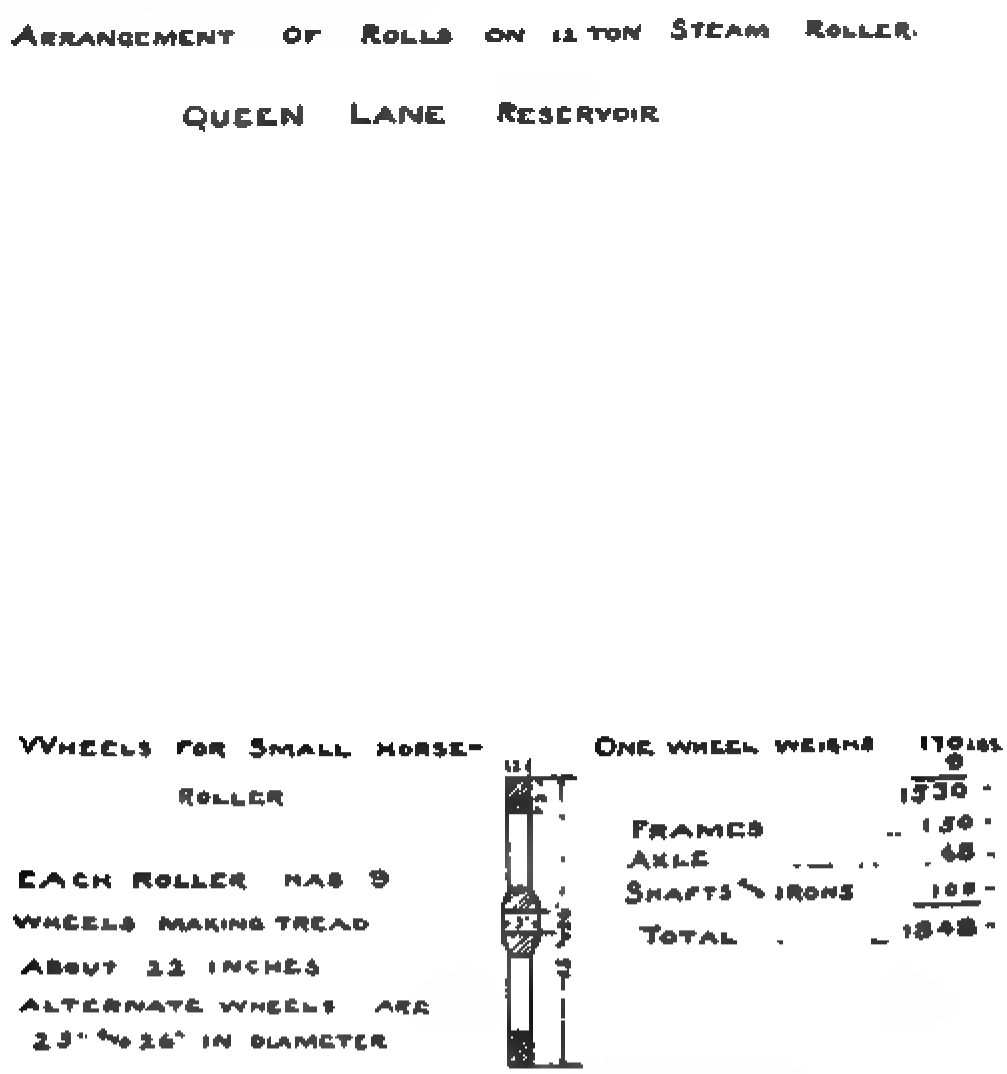


Fig. 3.

The work of building the banks was begun October 31, 1892. The material for the embankment was brought to place by wheel and drag-scrapers, carts, and trains from the steam-shovels. That delivered by the trains was dragged out in layers with drag-scrapers. The material of the bank on the inner side of the puddle wall contained comparatively few large stones, while in the outside filling the number of large stones is considerably greater. The material under the concourse and roadways, and beyond the

outer slopes of the typical bank, is the poorest taken from the excavation, and contains stones varying in size from a few inches to 18 or 20 cubic feet. The concourse, having been used also as a waste dump, contains refuse building material, top soil and stumps. The material under the concourse and roadways was not rolled. The contractors were authorized to make the fill, above the water line, from the rotten rock stratum, and, although this portion was rolled with the steam-roller, there are a number of unbroken large stones above that level. The embankment

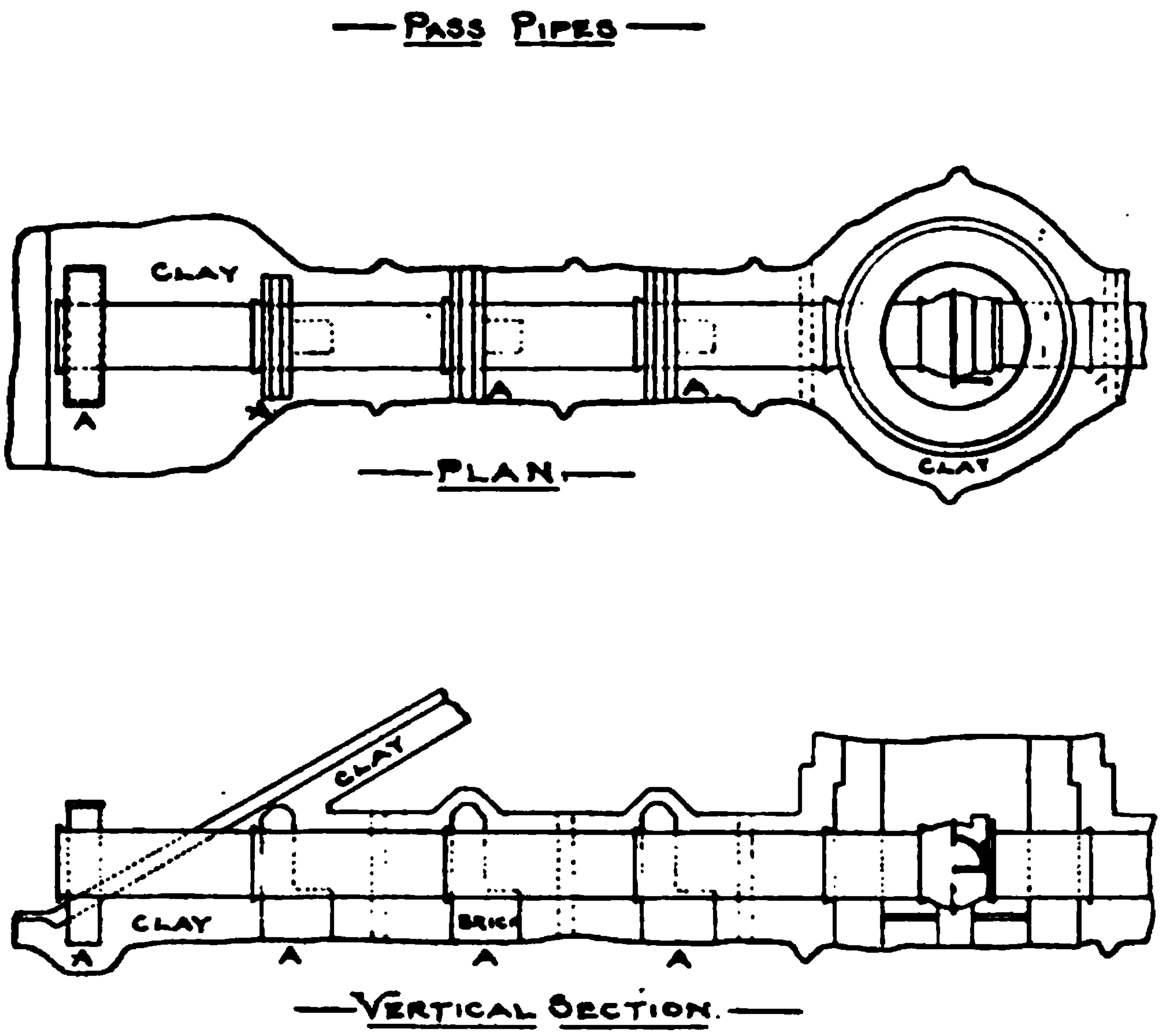


FIG. 4.

was rolled in layers of from 6 to 9 inches with two grooved steam-rollers (Fig. 3), each weighing 12 tons. Sprinklers were used to moisten the material, except after a rain. Within the enclosure formed by the embankments, the material immediately under the top soil was removed by wheeled and drag scrapers and carts. The lower strata were removed by drag scrapers (on the part next to the banks), by wheeled scrapers (nearer the center), and by steam shovels (in the central portion). Where the sub-grade was in rock, the excavation was made from 4 to 8 inches deeper

than sub-grade, in order to leave as few points as possible projecting above sub-grade. The bottom was then staked off in squares of 50 feet on a side, and the ground was carefully leveled between these stakes, the hollows being filled with decomposed rock, which was then rolled with a 12-ton grooved steam-roller (Fig. 3). Any small projections still remaining above sub-grade were removed with rock wedges and picks; larger projections were removed by blasting. Where the surface under the top soil was lower than sub-grade, viz.: in the northwest corner of the north basin (See Fig. 1) and (to a very small extent) along the south bank of the south basin, the surface was brought up to sub-grade by filling in with "best filling material" deposited in layers, as in the banks, and rolled with the grooved steam-roller, shown in Fig. 3.

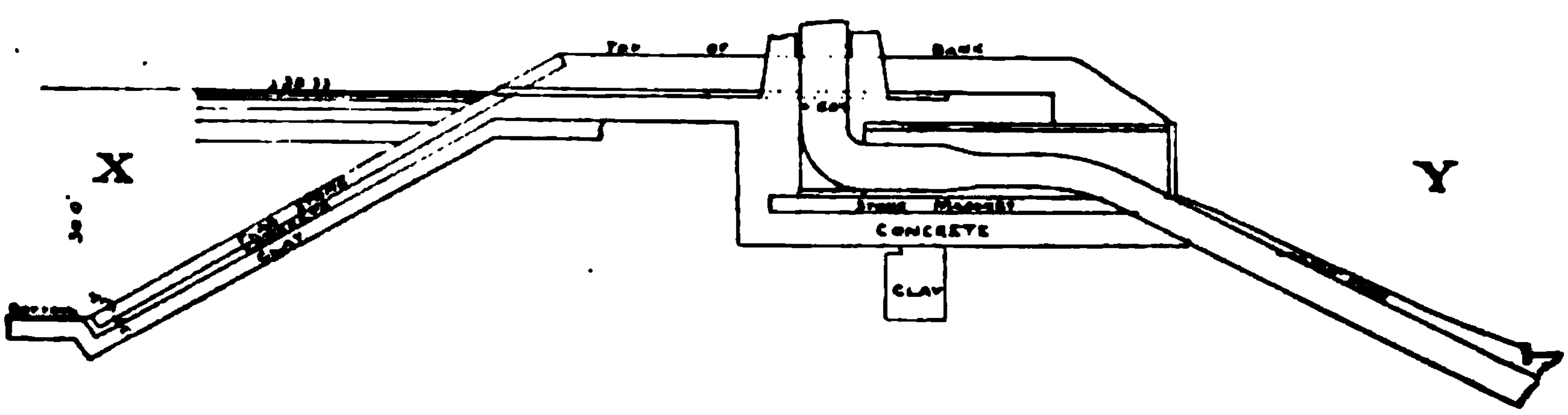


FIG. 5.

Pass-pipes, Fig. 4.—Where the lower pass-pipes are laid through the division bank (Fig. 4), the trenches are thoroughly rammed with clay from the bottom to 18 inches above the pipe, and for 18 inches around the well.

The piers A, A, supporting these pass-pipes are built T-shape in plan, the arm indicated by the dotted line running out about 2½ feet from the pier, thus giving about 4½ feet support to every joint. The sides of the trenches are grooved vertically between every two piers, as shown, so as to give a broken surface to the clay puddle along the side. On each side of the well the clay puddle is counter-sunk in the bottom of the trench about 15 inches. The upper pass-pipes were laid upon T-shaped piers in

the same manner as the lower ones, and the space between the pipe and surrounding piers was rammed with clay. The clay was also continued around the stop-well in the center of the bank.

Inlet Pipes. Fig. 5.—The two 48-inch inlet pipes are laid up the outer slope of the bank, from its foot at Thirty-third and Bowman Streets, to the vault under the inlet pool. They have about two feet of earth covering on the slope, and within the vault they are laid upon a series of brick piers which rest on a foundation consisting of rubble masonry 2 feet in thickness, over a layer of concrete 4 feet thick. At the rear end of the vault the two 48-inch pipes converge into a 72-inch pipe which makes a quarter turn into a vertical position, emerging from the embankment at the center of the inlet pool, from which the water flows into the two basins over aprons lined with blue-stone slabs set on edge.

Stop-Houses. Fig. 6.—The spaces between the stop-houses and the sides of the excavations and embankments adjoining them, are thoroughly rammed with clay, as indicated in Fig. 6.

Clay Lining.—The bottom and the inner slopes of the reservoir (Fig. 2), are lined throughout with two feet of clay taken principally from a field in the low ground just south of the hill on which the reservoir is built. Some clay was brought, also, from other localities within the City limits. The clay lining of the slopes was put on during the season of 1893, starting with the west bank in the north basin. After the completion of each bank the addition of its clay lining was begun. The clay was spread thinly, in horizontal layers, 2 or 3 inches thick, and kept moist by sprinkling with a hose. A line of one inch pipe was run around the entire bank, with hose connections spaced a short distance apart, to provide water for sprinkling purposes, and afterward for mixing the concrete. The clay was rolled with an iron-grooved roller, weighing about one ton, and drawn by two mules harnessed tandem. The clay for the bottom lining was delivered during the fall of 1893 and the winter following, and but a small portion of it was rolled in place before the spring of 1894. It was rolled in five or six layers parallel to the bottom of the reservoir, with a steam roller weighing 12 tons (Fig. 3), and, except where moistened by rain,

was sprinkled by sprinkling carts and wagons. Upon the slopes this clay is overlaid with concrete slabs 10 feet wide, 66½ feet

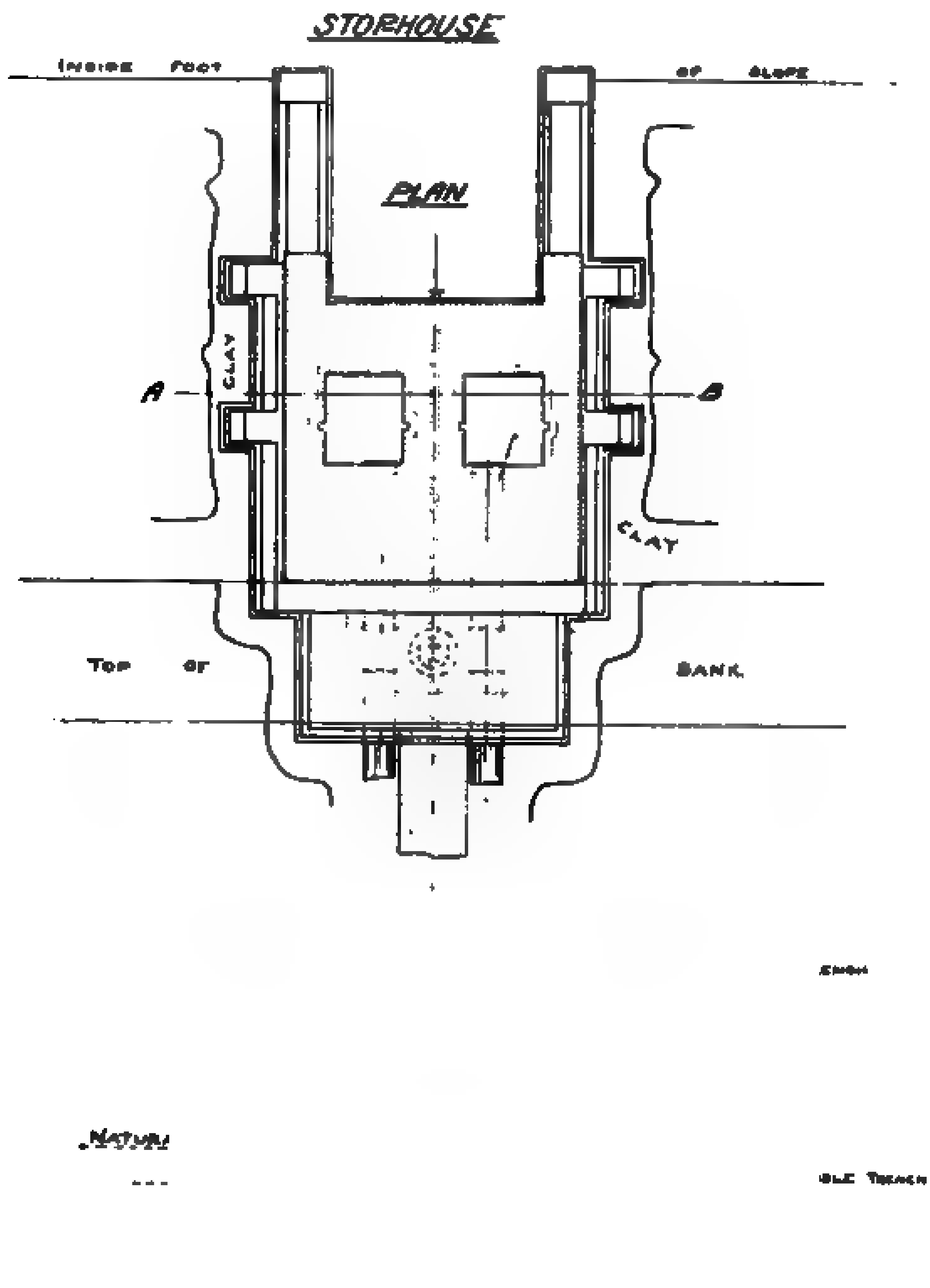


Fig. 6.

long, and varying in thickness from 6 inches at the top to 12 inches at the foot. (Fig. 2.)

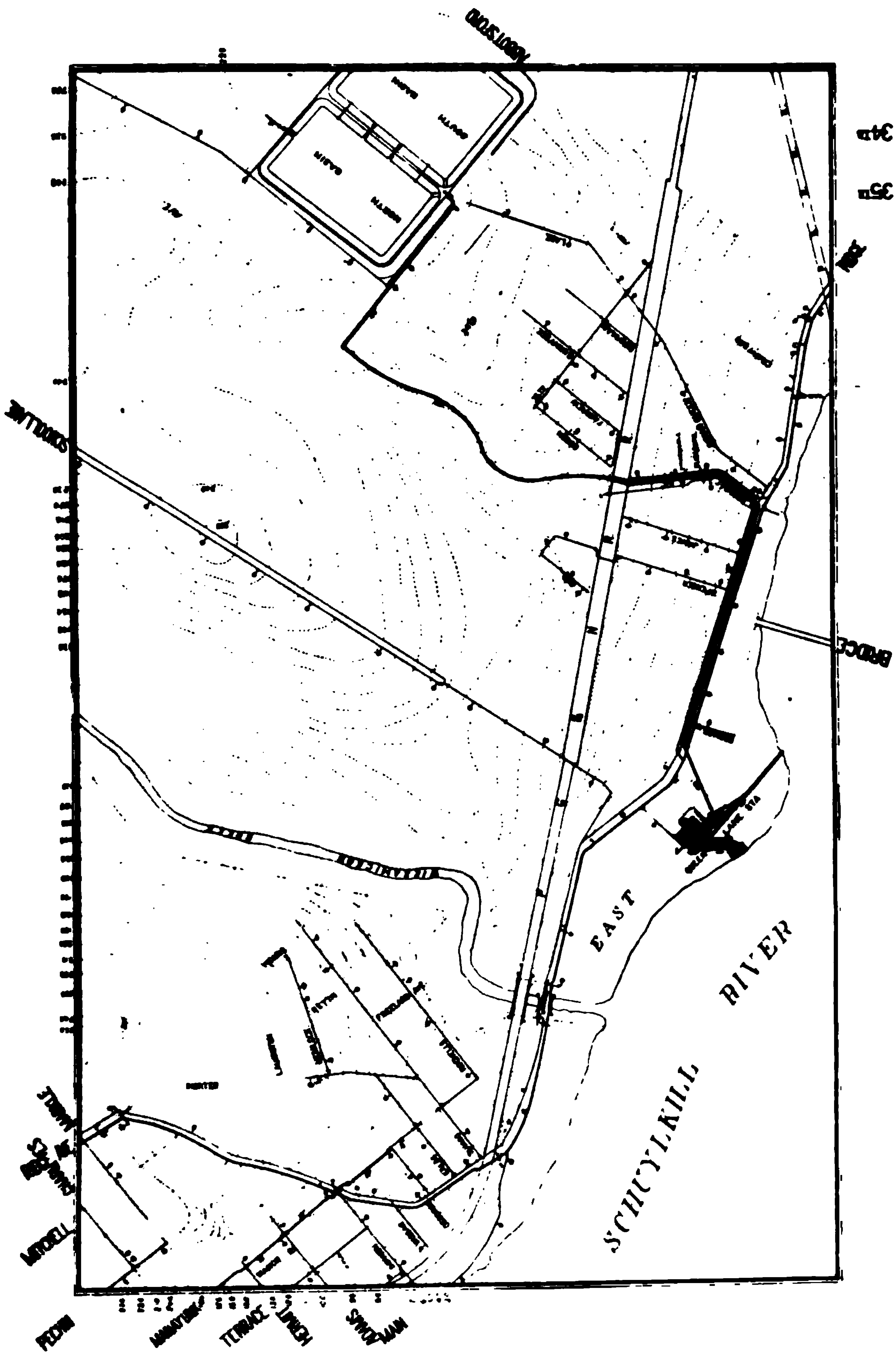


FIG. 7.—PLAN SHOWING LOCATIONS OF PUMPING STATION, PUMPING MAIN AND RESERVOIR.

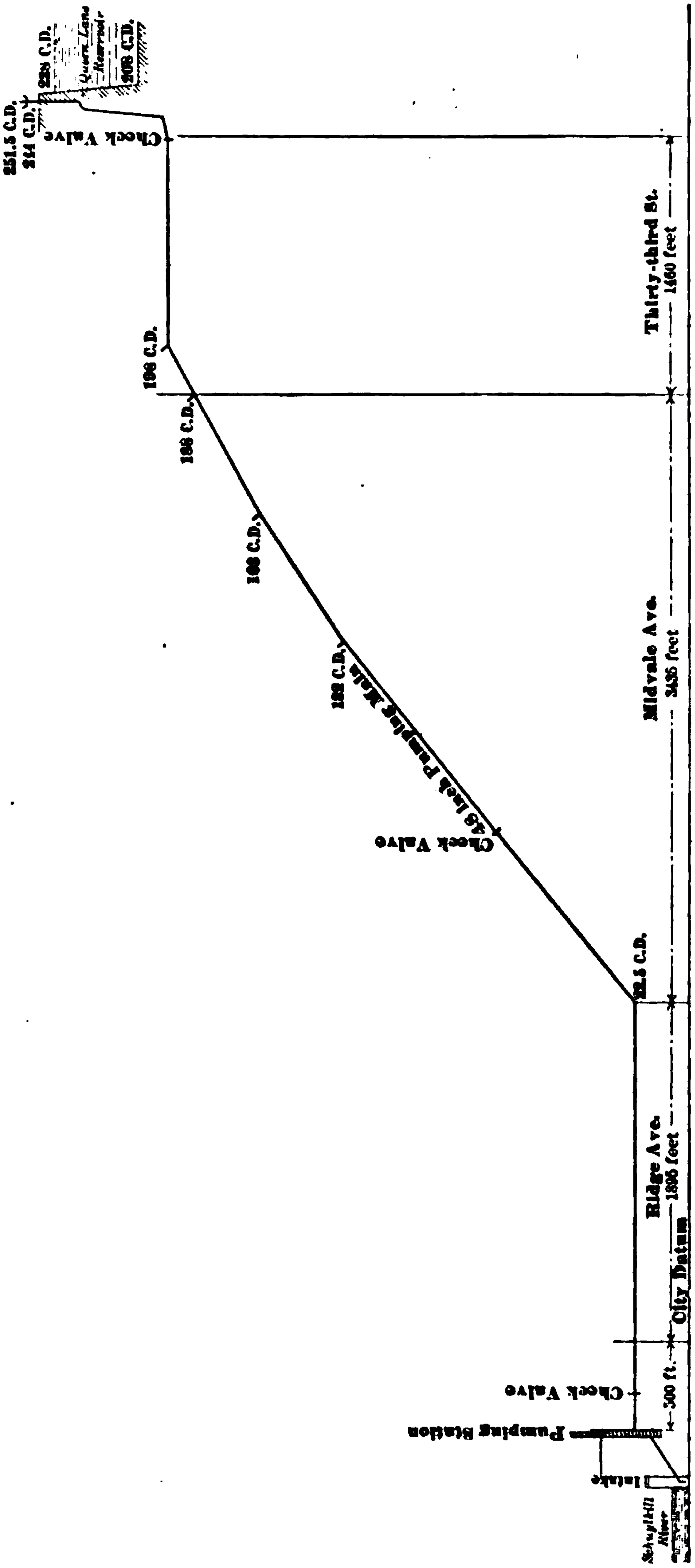


FIG. 8.—PROFILE OF PUMPING MAIN.

[Proceedings Engineers' Club of Philadelphia, Vol. XIV, No. 1, April, 1897.]

Fig. 9.—Laying Cement Concrete on Inner Slopes.

[Proceedings Engineers' Club of Philadelphia, Vol. XIV, No. 1, April, 1897.]

Fig. 10.—Laying Cement Concrete on Floor.

Fig. 11.—Stop-House.

Concrete Lining.—These slabs are supported entirely by the clay lining underneath them. The bottom of the reservoir is covered by a concrete lining 4 inches in thickness, which rests upon the clay lining. The edges of this bottom lining of concrete overlap the feet of the concrete slabs on the slopes as indicated in the figure. The concrete for the bottom and slope lining was mixed as follows: Two parts of sand and one part of cement were spread evenly upon the mixing board, and turned and raked until well mixed, when enough water was added to make a thin mortar, after which four parts of broken stone were spread evenly over the mortar and mixed with it. In a portion of the bottom lining of the south basin, blast-furnace slag was substituted for the stone. After the bottom concrete was rammed in place until the mortar appeared on the surface, a dryer, composed of one part cement and two parts sand, was thrown over the surface, which was then floated until all stones appearing on top were covered, and a comparatively smooth finish obtained. On the slope concrete, a separate finish, composed of one part cement and two parts sand, was used. The slope concrete and finish are of the same character as that placed as a sample in East Park Reservoir. The cement used on the lining was all imported, and of the Hilton, Burham and Hemmoor brands. With the exception of shaping up the outer slopes in a few places, and a few square yards of sodding, the work was finished by October 1, 1894.

DISCUSSION.

MR. JOHN BIRKINBINE.—It was not my purpose to discuss the Queen Lane Reservoir at this time, but as the President has called me to my feet I would say that while the location selected may not have been advisable, or the best that could have been secured, the fact that the territory on which the reservoir is located now supports its embankments, and the large amount of water they contain, prove that the locality was not responsible for its leaking. In the absence of the one whom Mr. Trautwine says had a more intimate knowledge of Queen Lane Reservoir than any one else it is difficult to discuss details which have not been presented. This reservoir has been before the public and

before the court, and some very severe strictures have been made upon it, but it seems to me that we can learn two lessons, without intimating any dishonesty on the part of anyone connected with it either in the capacity of engineer or contractor.

The first of these lessons is in making our specifications complete and thorough; the second is in seeing that the specifications are lived up to, without change. While the specifications were evidently imperfect in a number of particulars, a careful examination of them convinced me that a proper interpretation of their provisions in the light of the duty expected of the reservoir would have produced work of a satisfactory character and prevented the scandal which has fallen upon this work.

From investigations I am lead to believe that changes from the specifications are largely responsible for the defective condition of the reservoir. The use of puddling material which had been interdicted cannot be excused, and while the substitution of concrete slabs for brick lining may have been suggested by the contractors, and accepted by the Bureau in the belief that it would be an improvement, this change seems to me to be largely responsible for the defects which developed. We would scarcely consider a series of slabs, over 60 feet in length, 10 feet in width, ranging from 6 to 12 inches in thickness, as desirable to be laid on a well compacted and settled street, but such slabs were placed upon new earth slopes, and any settlement jeopardized their integrity. Continuous joints between slabs running from top to bottom of slope made gutters down which a considerable volume of water flowed, and overflowed, while the reservoir was under construction, and wherever these slabs cracked, opportunity for the water to cut a way to the puddle was offered. Had brick lining been used it would have settled with the bank, and showed any imperfect work, but it may be possible with the concrete slabs to have large cavities undiscoverable until the pressure on the slab caused breakage.

MR. L. Y. SCHERMERHORN.—With our attention now directed to the difficulties involved, present conclusions are more the result of hindsight than foresight. We can now see what the difficulties were; but when the suggestion is made that the specifications should have adequately provided for all the conditions

of construction as determined by experience, I should be inclined to take issue. I do not believe that specifications can be drawn to cover a large work of that kind—unless based on inspiration—which will apprehend at the beginning, from the planner's standpoint, all the conditions likely to arise in construction, so that necessary provision can be made therefor. It seems to me that it should be results that are aimed at, rather than a specified series of instructions to contractors how to accomplish such results. Would it not be better in works of this kind that the results be guaranteed, and the contractor not tied hand and foot with detailed specifications? I do not believe that the human mind is so constituted that it can apprehend all possible contingencies and difficulties likely to arise. Of course it opens up this question; if it is results that are aimed at, the contractor should not be bound to detailed plans: since if so bound he has no discretion in the matter, and is not responsible for results which may follow.

Now as to the question to which Mr. Birkinbine alludes specifying concrete slabs for the covering to the interior slopes. Very probably, in the light of experience, brick pavement might have been better, but under the supposition that the concrete slabs were to be thoroughly constructed, and not exposed to any marked tendency to settlement, then settlement would naturally not be anticipated. If you presuppose large concrete slabs of maximum integrity, with uniform settlement of the slopes, then such slabs would not interfere with the proper action of a covering which extended over very large surfaces.

In this same connection it seems to me that great reliance must be placed on puddle-walls. I remember thirty years ago a statement made by William McAlpine, who probably stood at the head of the profession of his day, as an engineer with very large experience, who had been called upon to design reservoirs which involved some of the largest systems of water works in the United States. If I remember rightly he objected to clay pure and simple, under the general statement that the purer the clay the poorer the puddle wall. The puddle wall he recommended above all others, as meeting the requirements of a proper puddle wall, was one composed of coarse gravel, free from sand, with the interstices between the particles of gravel thoroughly filled

with loam. That was his ideal puddle wall, and I remember his dwelling upon its advantages at length.

I have never seen such a puddle wall built, but from what I know of Mr. McAlpine I feel assured that it was not pure theory with him, but rather conclusions based on experience. In the discussion that followed, he called attention to the advantage of a puddle wall of the kind described. An ordinary clay puddle wall might have openings through it which went on enlarging and undetected until it suddenly gave way, while in a puddle wall built of the materials indicated, gravel mixed with loam, a small opening would be immediately closed with material falling down into it from above, and the disintegration of the wall indicated and arrested by a sinking of the material at the top of the wall.*

MR. BIRKINBINE.—I fully agree with Mr. Schermerhorn's criticism as to inelastic specifications, and, as I have stated in another discussion, consider these as unwise. My reference to the Queen Lane specification may be illustrated by the statement that the details of fence construction which was to go around the completed reservoir, specified the exact size and spacing of holes in the posts, and even the size of screws to be used, but left important matters, such as the method of placing the puddle in the bottom, to be determined by inference rather than direct phraseology.

MR. E. M. NICHOLS.—I have not had much experience in building reservoirs myself, but referring to the lining and the bottom of a reservoir, it is a pretty hard matter to get a large body of concrete to stay in one place all the time. We have none of us seen a large slab of that kind stay intact, and this calls to mind a specification that the City Engineer of Minneapolis read to me, it being a part of the specifications of a storage reservoir now being built by that city. In that specification the lining and bottom was specified to be of concrete slabs or blocks, not less than six inches thick, not over four feet on any side, and one inch apart,

* Subsequently Mr. Edwin F. Smith informed me that he remembered the above statement of Mr. McAlpine, and had since used such puddle walls, composed of gravel and loam, with the greatest success.

the interstices to be filled up with asphalt cement. It appeared to me a good scheme, as it gave a large amount of elasticity not to be obtained in the larger slabs. I think recent repairs have shown that was a good thing to follow up so as to secure a large amount of elasticity and not to have units too large.

(Communicated Discussions.)

MR. EDWIN F. SMITH.—The details of construction of the Queen Lane Reservoir are so complicated that it would take up the time of the Club unnecessarily to undertake to cover the entire ground. Moreover, no less than three reports upon the plans and specifications and the character of the contract work have been made by expert engineers, so that it would seem idle to prolong the discussion.

I will therefore confine myself to calling attention to some essentials of reservoir construction, applicable not only to Queen Lane, but to all others of its class.

The subject under discussion is naturally divided into three parts, namely, the substructure, superstructure, and the character of the material employed in the construction.

First: The Substructure.—It will be recognized among those engineers who have had to do with the building of reservoirs, canals and hydraulic works in general, that it is exceedingly difficult to write a specification which will cover completely every detail of the substructure of such works. Very much depends upon the character of the earth or of the rock underneath.

By substructure I mean every part of the work, whether in excavation or embankment, lying below the natural surface of the ground. In the case under discussion and in all others in which the contract is made for a lump sum, it will readily be seen that it is of the highest importance that the nature of the ground should be thoroughly understood and exhibited on the plans for the information of contractors at the letting.

If it were permitted to base the contract upon yardage, and it were left to the discretion of the engineer in charge, to say to what depth the foundations should be carried, there would be no incentive on the part of the contractors to limit the quantity of

work to a minimum. The depth of puddle trenches, and excavation for bottom lining might then be left for determination as the work progressed. In the City of Philadelphia, however, all work done for the municipality must be for a lump sum, and we therefore tied to that condition in this case.

I would say that the first step in fixing the data for the specifications *for a lump sum contract*, after surveying the ground, and marking out the lines of the reservoir, would be the making of systematic borings to ascertain the character of the ground to determine the full depth to which the substructure must be carried. A number of random test holes over the area to be covered will not answer the purpose.

It must be known in advance what is to be the character of the superstructure, the cross-section of the embankments on all sides, the location and size of cove wall, if there is to be one, the size and location of gate houses, and any other parts which will be affected by the foundations upon which they are to stand.

Obviously, one of the most important of these is the cove wall, for I do not see how that detail could be omitted from such a reservoir as Queen Lane, on such a foundation. For a lump sum contract, soundings or borings should be made, say, 100 feet apart, in the center line of the cove wall, for the determination of the proper depth of foundation, and a profile of the same should be exhibited at the letting for the information of contractors. The same applies to cross-sections of the reservoir bottom, the foundation of gate houses, etc.

It is not enough to say what a contractor, when he engages to build a reservoir for a lump sum, *should deliver to the city one that will hold water*. The city takes upon itself, as one of the parties to the contract, the furnishing of the plans and specifications, and it should give to the contractor *all the details*. Nothing should be left in doubt. It should not even be considered that a change in the plans, such as raising the elevation of the bottom of the reservoir, will compensate a contractor for a lack of knowledge of the exact conditions at the letting.

In the case before us, it would have been much less expensive for the city to have furnished full details before a letting, than to have made the costly repairs necessary to add a concrete and

cement masonry footing wall under the inner slope after the completion of the reservoir, as a substitute for a properly founded core wall, omitted in the original plans.

I would urge, in drawing the specifications for reservoirs, whether formed by a single embankment across a valley for impounding purposes, or enclosed on all sides, and elevated above the surrounding country, as at Queen Lane, the necessity of providing in the specifications for carrying the foundations or substructure to a considerable depth below the natural surface, in order to prevent subterranean infiltration. This applies not only to the core wall or puddle trench, or whatever plan may be adopted to intercept the flow of water, whether from leakage or seepage, but also to the foundation of the embankment itself. In other words, a reservoir should not be built up from a natural surface rudely prepared by grubbing and clearing and carting off the top soil. Even so seemingly unimportant a matter as locking the outer half of the embankment into the natural surface should be carefully guarded in the specifications.

If the process I have indicated is followed, and the information exhibited on the plans, it becomes an easy matter for an intelligent contractor to bid upon the work with a reasonable certainty of coming out whole on the substructure, as that part of the work is not the most difficult of execution, and it is generally estimated upon at paying prices. It would also save the necessity of admitting, as has been done in the reports on the condition of the Queen Lane Reservoir, that, "in a number of places where the elevation of the surface was high, the foot of the core wall *was higher than the bottom of the reservoir*, so that the wall, even if impervious, could not have intercepted any leak having its origin at the level of the bottom of the reservoir."

Second: The Superstructure.—I know that I am treading on dangerous ground when I criticise the practice of the City of Philadelphia, in its plans for reservoir embankments, but I think it is not too late, as other reservoirs are in contemplation, to call attention to the fact that slopes from 2 : 1 to 2½ : 1 for the inner, and from 1½ : 1 to 2 : 1 for the outer slope, are necessary to insure stability, the precise inclination for earthwork varying to suit the character of the material used, and the height of the embankment.

In the case before us, the inner slopes are 1.64: 1, and the *minimum* outer slope before reconstruction 1.3: 1. Better use would have been made of the same quantity of material if the top width of embankment had been decreased, and the bottom width increased, resulting in flatter slopes. *Flat slopes are especially necessary when the material forming the embankment is of either a micaceous or a talcose nature.*

Also in the Queen Lane design, I do not like the position of the core wall. I would much prefer to place it under the center line of embankment, and to use a *concrete or masonry* wall of less cross-section, started in a trench, excavated in the solid rock, and carried up to a height of ten feet or more above the level of the natural surface of the ground. In a former discussion on reservoir construction, I said: "No dependence at all ought to be placed upon a *puddle* core in the heart of the bank. *Such construction inevitably leads to carelessness in the selection of material for the inner and outer slopes:* the inner slope being usually the best material obtainable in the vicinity, and the outer slope being the refuse of the borrow pit, dumped promiscuously outside the clay puddle wall; and as to this latter, *the purer the clay the more dangerous it becomes in case of a leak.*"

The puddle-clay core-wall construction leads to over-confidence in that part of the work. The contractor is apt to look upon it as the main protection against leakage, whereas it is just as important that the whole inner half of the embankment should be built of selected material *suitable for the purpose,* properly mixed and tempered and rolled to place.

Another detail which I am disposed to criticise, is the manner of supporting the pass-pipes. Years ago it was the almost universal practice to carry pipes through reservoir embankments on brick or stone piers, one to each joint, with the intervening spaces puddled with blue clay, and to some extent that method is still followed.

I have known some very bad accidents to follow such construction. In one case, that of an impounding reservoir carrying 41 feet of water, with embankment 47 feet high above the pipes, an accident occurred thirty-five years after construction, caused by the breaking of the pipes between piers set 9 feet from center

to center. This would have caused a disaster in the valley below the dam, but for its timely discovery.

Pipes should always be laid on a continuous foundation of cement masonry, or better, of concrete, carried up to the top of the pipe or nearly so. There should be cut-off walls or piers at intervals carried to a height of 18 inches or 2 feet above the top of the pipe.

Third: The Character of the Material Employed in the Construction.—I think it will not be questioned that a specification easily understood by contractors can be drawn for all the materials entering into reservoir construction, except for the embankments. Even the composition of cement concrete is now so well understood that there need be no misunderstanding of that detail. But when we come to the definition of puddle material, puddle clay, puddle formed of gravel and clay, etc., the descriptions in the specifications are apt to differ one from another quite as much as the materials themselves.

Mr. Clemens Herschel, C.E., once said in discussing the subject of the proper material for use in the construction of reservoir embankments: "This is a subject in which theory and its discussion must play a part subordinate to that of judgment *trained by sight and touch, in the actual handling of earth and gravel.*" (The absence of the word clay is noticeable.) And again: "The characteristics of the materials to be considered, although clearly enough impressed upon the mind of the practitioner, *are not readily defined in writing.*"

I quote, also, from Mr. Alphonse Fteley, C.E., who says: "I have often remarked the great divergence of opinions expressed by engineers, in regard to the quality of materials and to the methods of construction to be adopted, for the erection of structures wholly, or partially made of earth, and I think that such divergence must be largely attributed to the differences existing between the materials used, *which, although designated by the same general names* of earth, loam, sand, gravel, clay, hard-pan, etc., may represent widely different characteristics of size and composition."

I think it will be recognized that it is a difficult matter to accurately describe in a specification, a material the nature of

which can only be determined by sight and handling. It is likewise quite as difficult to describe in writing the manipulation and use of the same material when that is a matter which must be left to the practiced eye and trained hand of the skilled workman.

Therefore, when it is specified that the *clay* puddling must be formed of the *best material* obtainable *on the ground*, what assurance have we that the result will be *clay* puddling at all. A very much better description of *what constitutes puddle* is given by Mr. Herschel in the same article from which I have before quoted, who says: " As I understand the term, puddle is earth duly consolidated by the application of water. In and about Lowell, the fitness of a material for puddling was ordinarily tested, by placing in a pail of water, enough of it, to render the water invisible. The pail was then upset, and if the mixture dropped out, it was rejected, if it remained in the pail, it was considered satisfactory for puddling." I have myself used this method for testing sand for cement work, and I would add that it is necessary to agitate the pail long enough to bring all the water to the surface when it should be drained off before inverting.

We are told in one of the reports upon the Queen Lane reservoir that " *The core wall is composed principally* of sandy *clay found in places upon the site of the reservoir*," and that " the inner slopes and the bottom are covered with a layer two feet thick of clay, brought chiefly from a *field south of a reservoir*." *Also* as to the core wall, " we found it to be a decidedly sandy and inferior clay, so that the wall at best could have added but little, if any, to the water-tightness of the banks."

An almost ideal material for all that part of the work would have been a mixture in the proper proportions of Fairmount gravel, which is easily obtainable on city property, within three and a half miles of the reservoir, by rail, and the sandy clay found upon the site. I am aware that this will be looked upon as an innovation, involving unusual and unwarranted expense, but I am confident that it would have made a water-tight and satisfactory embankment, and would have saved money in the end.

Engineers in the United States have been too prone to follow

the English practice of clay puddle. It is hard to make radical changes, in specifications and methods of construction, when with few exceptions the engineering profession has been educated through a long term of years to believe differently. Such changes must come by degrees, as we become acquainted with better methods.

Prior to the reading of the above paper, Prof. LEWIS M. HAUPT, a visitor, was invited by the President to make a few remarks on the subject of reservoir construction, and spoke as follows:

I came here to listen, and not to talk. There is a great deal of value connected with the construction of this reservoir. It is one of the things we may learn something from, as we are told that engineers learn more by failures than by successes. It has been broadly claimed that all reservoirs leak. I do not believe the claim is correct, but it is broadly claimed to be, and that involves the question as to the distinction between leaking and seepage. I have no doubt that, in seasoning, material will suppurate slightly until the banks settle, and there will be a certain amount of water escaping. But I have read of a number of instances where reservoirs did not leak because they had been properly puddled. I think pure clay is not suitable for puddling, although many engineers do not agree on this point, and that it is one of the most dangerous materials to be handled, in consequence of its great ratio of expansion and contraction. There are other difficulties in the construction of a reservoir,—the proper connection of the superstructure with the base, for instance. We are anxious to have a new water-supply in West Philadelphia, and the construction of the Queen Lane Reservoir should furnish a valuable precedent as to the framing of specifications. It seems to me that the contractor should take the entire risk in building a reservoir and build it, to contain a certain number of millions of gallons of water, for a certain amount of money. This question arose in a certain case where a contractor had agreed to build a reservoir for a certain amount of money, but it was claimed that he had not guaranteed that it should hold water.

ALLEN J. FULLER.—The specifications for the construction of Queen Lane reservoir may not be above criticism, but it is hardly

fair to compare a specification for the construction of a fence with one for the clay lining of a reservoir.

In works of reference and in such specifications for the construction of reservoirs as I have been able to obtain, the description of clay puddle and puddle walls is exceedingly meagre, and the requirements mentioned are chiefly of value in proportion to the intelligence displayed in selecting the clay and in the proper supervision of the work. In conformity with modern practice, the specifications for the construction of Queen Lane reservoir are not lacking in any of the requirements necessary for the construction of a satisfactory clay lining, and, as has been stated, a good reservoir could be constructed under these specifications.

Professor Haupt's statement that "the claim sometimes made that all reservoirs leak, is an incorrect one," will hardly apply to new reservoirs which have been excavated in earth or to those constructed of earth embankments, for the reason that all soils are porous, to a more or less degree, and are therefore subject to a constant percolation of water through the walls and bottom of the basin, in proportion to the weight (specific gravity) and fineness of the lining used. Eventually, the percolation is almost entirely checked by the sediment that settles on the bottom and inner slopes, and in time, the result is a tight reservoir.

Owing to the fineness, durability and cohesive qualities of clay there is no better natural material for preventing the escape of water from reservoirs. In this respect, whether the clay be used pure or mixed with sand or gravel, the advantage of such a lining is universally recognized, and every failure in reservoir construction may quite readily be traced to defects in other parts of the work.

Apart from puddling, rolling, watering and otherwise manipulating the clay intended for lining a reservoir, the utmost care must be given to the foundation upon which the clay is to be set. The foundation should be as firm as possible, though a slight settlement will not be detrimental. The surface upon which the clay is to rest, must also be of sufficient fineness to prevent any appreciable absorption of the clay and yet be sufficiently porous to readily carry off the water that may percolate through it. In

the latter event, the clay will remain hard and tough; otherwise, there will be a back pressure which will proportionately reduce the cohesion of the clay particles, and thus possibly permit the direct pressure of the water to be transferred to the foundation surface. This may result in opening a course for the water, and in case of a sudden relief, may partially or completely rupture the clay lining. The danger of back pressure, however, where the embankment is of earth and recently built, is slight; but where there is a hard rock formation, or an old embankment or bottom surface which has been constructed and exposed to the weather for a considerable length of time and has become water-tight, there is a great possibility of a back pressure, which must either find a course beyond the basin or result in so thoroughly soaking the clay as to render it liable to slide on the slopes. Under these conditions, clay might be considered "a dangerous material."

The protection of the upper surface of the clay lining is an important feature in reservoir construction, and it gave me much pleasure to hear Mr. Birkinbine approve of "a brick lining on the clay, laid dry." A lining of brick, stone, or of a material similar to these, laid without cement or mortar, will readily conform to any inequalities which may occur by settlement, and will tend to seal an incipient leak. With a flexible protective lining of this kind, serious defects may be readily distinguished by resulting depressions, which would probably remain unobserved where a concrete or rigid lining is used. I think, in the construction of reservoirs, where dependence is placed upon this material for preventing undue percolation or leakage, a rule to use a flexible lining of dry-laid bricks, stone or blocks, for protecting the clay, should be adopted; and that the use of a rigid lining, such as continuous sheets of concrete or masonry, with or without a non-porous coating, should never be permitted, unless of sufficient strength, durability and imperviousness to be relied upon without a clay backing.

There have been many criticisms of the site selected for the Queen-Lane reservoir, owing to the character of the material upon which it is built; but it should be remembered that there are no sites, of sufficient area and elevation for the construction of

large reservoirs available in the city and county of Philadelphia, which do not present the same geological features. Micaceous rock and soil do not constitute a bad or dangerous material upon which to build a reservoir, but great care should be exercised in preparing the foundation upon which the embankments are to rest, as well as the surface on which the clay lining is to be laid. If these precautions are taken there need be no apprehension of serious trouble in constructing, on such material, a water-tight reservoir.

NOTES AND COMMUNICATIONS.

RAILROADS IN JAPAN.

At the meeting of January 16, 1897, Messrs. H. Iwasaki, Kobe, and K. Nagatani, Tokio, visiting Japanese engineers, furnished some information on the subject of Japanese railroads. There are now about 2300 miles of railway in Japan, of 3 feet 6 inches gauge, about half the mileage being under government and half under private control. These roads have all been built in the past twenty-five years. Most of the locomotives are of the American pattern, while the other rolling stock is of the English plan. Passenger cars are small, holding from 15 to 20 persons. Most of the rolling stock is imported to the country, but the government shops have built six locomotives and many passenger cars. In constructing the roads, 60-pound rails are used, laid upon cross-ties of native wood resembling the fir of this country. Bituminous coal is the fuel burnt in the locomotives. The engineers are all native. At present there is in Japan but one electric railway, about 6 miles long, which is in the city of Tokio.

ACCURATE DISTANCES IN PHILADELPHIA FOR CALIBRATING CYCLOMETERS.

At the meeting of March 20, 1897, Mr. Carl Hering presented a list of distances on nearly level, asphalted streets, compiled from the large plans of the Survey Department. They may be relied upon as being correct, and may be used for testing cyclometers. They have been checked, through the kindness of Mr. George S. Webster, Chief Engineer of the Bureau of Surveys. They are the horizontal distances, no allowance being made for the slight grades.

On Broad Street, from the middle of Brandywine Street, east side of Broad, to the south curb of Oxford Street is exactly one mile.

From the south curb of Spring Garden Street (east side of Broad Street) to the north house-line of Cumberland Street is 30 feet more than 2 miles.

From the north house-line of Brandywine Street (on the east side of Broad) to the south house-line of Tioga Street is 50 feet more than 3 miles.

From the north curb of Spring Garden Street (east side of Broad) to the south curb line of Cayuga Street is 60 feet more than 4 miles.

On Diamond Street, from the west house-line of Broad Street to the east curb-line of Thirty-third Street is nine feet more than $1\frac{5}{8}$ miles. Four times this distance is therefore only a few feet more than $6\frac{1}{2}$ miles.

From the east curb of Thirty-third Street to the west house line of Broad Street and back to the west house-line of Thirtieth Street is 20 feet less than 3 miles.

ANNUAL REPORT OF THE BOARD OF DIRECTORS.

FOR THE FISCAL YEAR 1896.

JANUARY 16, 1897.

TO THE ENGINEERS' CLUB OF PHILADELPHIA,

Gentlemen:—In compliance with the requirements of the By-Laws, the Board of Directors offers the following report of the affairs of the Club for the year ending December 31, 1896:

During the year eighteen regular meetings of the Club were held, at which the maximum attendance was ninety-nine, and the average seventy-four as against sixty-nine during 1895.

Ten regular and eight special meetings of the Board were held, which were well attended, except one special meeting, at which a quorum was not present.

The Board recommends that an extra effort be made to increase the membership.

The Board has given much attention to arrangements for the satisfactory conduct of the business of the Club. It has adopted comprehensive rules for the government and operation of the standing committees, providing, among other matters, that each committee should formulate rules for its guidance and keep minutes of its meetings.

The annual reports of the standing Committees to the Board are herewith presented:

MEMBERSHIP COMMITTEE.

During the year twenty-six Active and three Associate members have been elected; seventeen Active and two Associate members have resigned; fifteen Active members have been dropped, and eight Active members have died. These changes have resulted in a loss during the year of thirteen in the total membership of the Club.

The record of deaths is as follows:

John B. Fontaine, died January 6, 1896.
Thomas D. Whitaker, died March 7, 1896.
Edward R. Zoll, died March 18, 1896.
Edward Samuel, died March 27, 1896.
Louis P. Evans, died August 19, 1896.
T. Roney Williamson, died September 12, 1896.
Amasa Ely, died December 2, 1896.
Oliver E. McClellan, died December 9, 1896.

The number of members on December 31, 1896, was as follows:

Class.	Resident.	Non-Resident.	Total.
Active	282	120	402
Associate	13	2	15
Honorary		1	1
	295	123	418

INFORMATION COMMITTEE.

In the arrangement of the program of meetings, the Committee has endeavored to make provision, in so far as practicable, for the great diversity of interests represented in the membership of the Club. A list of the papers presented during the year is given below. In view of the rapidly-increasing importance of electrical engineering, it is especially noticeable that no less than five papers were devoted to electrical subjects, four of which relate to the application of electricity to engineering.

List of papers presented during 1896:

JANUARY 4.—Distribution of Electrical Energy from a Central Station. By William C. L. Eglin.

JANUARY 18.—Annual Report of Board of Directors. Annual Address of President.

FEBRUARY 1.—The Queen Lane Division of the Water-Supply of Philadelphia. I. The Boilers. By John E. Codman.

FEBRUARY 15.—The Queen Lane Division of the Water-Supply of Philadelphia. II. The Pumping Engines. By Thomas H. Mirkil, Jr. III. The Engine and Boiler Houses. By Frank L. Hand.

MARCH 7.—Water-Renaissance. By John Birkinbine. Construction-Work on the Croton Aqueduct and views of some specimens of Ancient Plumbing. By Henry Leffmann.

MARCH 21.—Sewage Disposal at Wayne, Pa. By Thomas G. Janvier.

APRIL 4.—On Cantilever Bridges. By Edgar Marburg.

APRIL 18.—Discussion on the Adoption of the Metric System.

MAY 2.—The Welsbach and other Incandescent Gas-Lights. By George S. Barrows.

MAY 16.—Business Meeting for Discussion of Proposed By-Laws.

JUNE 16.—The Electric-Storage Battery. By Rudolph H. Klauder.

SEPTEMBER 19.—The Water-Supply of Philadelphia Considered with Reference to the Minimum Flow of the Schuylkill River. By Edwin F. Smith.

OCTOBER 3.—The Cement-Laboratory of the City of Philadelphia. By Richard L. Humphrey.

OCTOBER 17.—Roentgen Phenomena; Theory and Practice. By Elmer G. Willyoung. Electricity in Gold-milling. By Henry M. Chance.

NOVEMBER 7.—The Queen Lane Division of the Philadelphia Water-Supply System. IV. The Distributing System. By Allen J. Fuller. Rapid Methods in Instrumental Drawing. By Lino F. Rondinella.

NOVEMBER 21.—Professional Ethics among Engineers. By Charles Piez.

DECEMBER 5.—The Storage-Battery in Electric-Traction Work. By Charles Hewitt.

DECEMBER 19.—Topical Discussion. Some open Questions Concerning Structural Steel.

(*a*) The Influence of Various Agencies in the Course of Manufacture. By H. H. Campbell and Albert Ladd Colby.

(*b*) The Practicability of Using the Higher-Carbon Steels. By Frederick H. Lewis.

(*c*) The Influence and Effect of Dynamic Stresses on the Material and Structures. By James Christie.

The plan adopted this year of issuing an advance program of papers seems to have met with general approval, and the Committee advises its continuance.

By the new regulations, two meetings during the years are to be regularly devoted to "Topical Discussions." To make these meetings as profitable as possible, members are urged to assist the Committee by the suggestion of subjects.

The regular employment of a stenographer for reporting the proceedings at meetings has greatly facilitated the work of the Publication Committee and Secretary, and has added materially to the value of the discussions.

Publication Committee.

Since its last report the Committee has issued four numbers of the Proceedings, containing a total of 304 pages of printed matter, exclusive of advertisements. Each number has been issued on time. Only in one case was there a delay in the publication of a paper, and for this delay the author was responsible.

During the past year the Committee drew up a five-year contract with a publishing firm, according to which the Proceedings are published free of all charges to the Club, other than for the postage. The last two numbers (July and November) were published under this contract, and the new system seems to be quite satisfactory in every way. This contract provides for an increasing number of pages, illustrations, and number of copies, without any cost for the increase. The Club is thereby relieved of some expense, and the Publication Committee of much labor and of the duty of soliciting advertisements.

The January and April numbers were published by the Club as heretofore, and the amount short of paying full cost was $116.96.

The Committee has had under consideration the question of publishing the Proceedings monthly during ten months of the year, and considers it quite feasible. That it is desirable, if it can be done without expense to the Club, there is no question, as the papers can then be published with less delay. The Committee recommends to the incoming Board to make this very desirable change.

Library Committee.

All the leading engineering journals have been supplied regularly, and many valuable additions have been made to the library by gift or in exchange. The Committee recommends the establishment of the office of Librarian.

ANNUAL REPORT OF THE TREASURER.

FOR THE FISCAL YEAR 1896.

Receipts.

Dues and Initiation Fees:		
1894	$15 00	
1895	270 00	
1896	4,655 00	
1897	65 00	
		$5,005 00
Advertisements:		
1894	$18 00	
1895	136 00	
1896	293 00	
		447 00
Proceedings:		
1895	$6 50	
1896	86 84	
		93 34
Reprints:		
1895	$17 00	
1896	39 75	
		56 75
Interest on Deposits		12 72
Keys		4 00
Donation Electrical Engineers		31 00
Total Income		$5,649 81
Cash Balance, Dec. 31, 1895		390 21
		$6,040 02

Expenditures.

Salaries:		
Secretary	$240 00	
Treasurer	60 00	
Clerks	590 50	
Janitor	300 00	
		$1,190 50
House:		
Rent	$1,100 00	
Coal	93 25	
Gas	54 77	
Ice	18 30	
Repairs, Supplies, etc.	131 66	
		1,397 98
House Improvements:		
Furniture and Fixtures		396 43
Secretary's Office:		
Stamped envelopes, stationery, postage and supplies		202 00
Proceedings		500 45
Notices		540 89
Treasurer's Office		81 30
Information Committee		63 99
Library		70 20
Luncheons		677 50
Affidavit of Tellers		5 00
Reprints		30 25
Advertisements, 1896		6 00
Total for 1896 account		$5,162 49
1895 Accounts paid:		
Stern & Co.	$330 29	
Sherman & Co.	37 50	
H. Veit	74 00	
Rent	275 00	
Ice	18 25	
C. L. Prince	6 25	
Williams, Brown & Earle	2 30	
Ed. E. Light Co.	9 33	
McFarland's Son	11 25	
		764 17
Total Disbursements		$5,926 66
Cash Balance, Dec. 31, 1896		113 36
		$6,040 02

Respectfully submitted,

GEORGE T. GWILLIAM, *Treasurer.*

House Committee.

The House Committee, during the year, has endeavored to continue the work of the previous Committee toward making the Club-House attractive. To this end, new furniture has been purchased. A new leather settee and three arm-chairs have been placed in the lower sitting-room, and new theatre chairs have been placed in the lecture-room, replacing the camp-stools formerly used.

The quality of the luncheon served after each meeting has been improved, and the quantity provided has been increased, owing to the increase in average attendance.

A system of Membership Cards has been introduced, and an attendant has been placed at the door on meeting nights to prevent unauthorized persons from obtaining admission to the Club-House.

The House Committee would remind the members of the Club that the Club-House being now in a comfortable condition, warrants a larger use being made of the rooms and facilities of the House than is at present the custom.

Finance Committee.

Assets and Liabilities, December 31, 1896.

Due for Proceedings and Advertisements	$19 75
Dues for 1896	500 00
Cash on hand	113 36
	$633 11
Liabilities, Dues for 1897 collected in 1896	65 00
Balance	568 11

Estimates and Expenditures.

	Expenditures for 1895.	Estimate for 1896.	Expenditures for 1896.	Estimate for 1897.
Salaries	$1,105 00	$1,200 00	$1,190 50	$1,200 00
Proceedings	903 38	1,100 00	500 45	....
House	1,336 40	1,400 00	1,397 98	1,400 00
Luncheons	607 00	600 00	677 50	800 00
Notices	362 43	450 00	540 89	600 00
Secretary's Office	164 26	250 00	202 00	250 00
Treasurer's Office	40 35	50 00	81 30	100 00
Library	78 40	250 00	70 20	250 00
Information Committee	142 00	150 00	63 99	150 00
Sinking Fund	465 53	....	....	....
Miscellaneous	39 00	50 00	41 25	100 00
House Improvements	463 79	....	396 43	....
Liabilities of 1895 paid	....	....	764 17	....
Total Expenditures & Estimates	$5,707 54	$5,400 00	$5,926 66	$4,850 00

Respectfully submitted by order of the Board of Directors,

A. Falkenau, *President.*

L. F. Rondinella, *Secretary.*

ABSTRACT OF MINUTES OF MEETINGS OF THE CLUB.

BUSINESS MEETING, January 2, 1897.—The President, Arthur Falkenau, in the chair. Sixty-eight members present.

The amendments to the By-Laws were fully discussed and ordered to be voted upon for adoption by the Club on January 16, 1897.

The Special Committee appointed for the purpose presented a memorial of Amasa Ely, late member of the Club.

On account of the lateness of the hour, and at the request of Mr. G. B. Hartley, his paper on "Steam Boilers as the Inspector finds them," was postponed until February 6th.

EIGHTEENTH ANNUAL MEETING, January 16, 1897.—The President, Arthur Falkenau, in the chair. Ninety-six members and visitors present.

The President presented the Annual Report of the Board of Directors for the year 1896.

The retiring President, Mr. Arthur Falkenau, presented the paper of the evening upon "The Engineer as a Moral Force."

Messrs. H. Iwasaki and K. Nagatani, visiting Japanese engineers, were requested to address the Club on the subject of Japanese railroads.

The Tellers reported that 186 legal votes were cast, electing Mr. George William Moreton to active membership and Mr. J. Ogden Hoffman to associate membership in the Club.

The Tellers reported that 212 legal votes were cast, of which 197 votes were for and 33 votes were against the adoption of the amendments to the By-Laws, Article I, Sections 1 to 7; Article V, Sections 3 and 4; Article VI, Sections 1 and 2. These amendments were therefore adopted.

The Tellers reported that 242 legal votes were cast for officers for 1897, and gave in detail the number of votes received by each nominee. The President, in accordance therewith, reported the following elected:

OFFICERS FOR 1897.

President—Joseph T. Richards.
Vice-President—Henry Leffmann.
Secretary—L. F. Rondinella.
Treasurer—George T. Gwilliam.
Directors—William C. L. Eglin, G. B. Hartley, F. Schumann.

BUSINESS MEETING, February 6, 1897.—The President, Joseph T. Richards, in the chair. Sixty-nine members and visitors present.

The Secretary announced that Mr. George B. Roberts, active member of the Club since November 19, 1881, died on January 30, 1897. Upon motion, the President was requested to appoint a committee to prepare a suitable memorial.

The amendment to the By-Laws, Article IV, Section 7, fourth paragraph, second sentence, by inserting the words "at least," so as to make the sentence read, "It shall publish during each year at least four numbers of the Proceedings of the Club,"

etc., was then discussed, and upon motion it was accepted in the latter form to be voted upon for adoption at the meeting of February 20th.

Mr. George B. Hartley presented a paper on "Steam Boilers as the Inspector finds them." The descriptions were illustrated by lantern slides and specimens.

BUSINESS MEETING, February 20, 1897.—The President, Joseph T. Richards, in the chair. Seventy-nine members and visitors present.

The Tellers reported that sixty-nine votes had been cast for, and five against the adoption of the amendment to Article IV, Section 7 of the By-Laws. The amendment was therefore adopted.

Mr. P. Kreuzpointner (visitor) read a paper on "Steel as Viewed by the Engineer," and illustrated his remarks with a series of specimens of steel and a number of diagrams.

Mr. Joseph T. Richards presented a communication on "The Future Habitation of the Club."

BUSINESS MEETING, March 6, 1897.—The President, Joseph T. Richards, in the chair. Fifty-eight members and visitors present.

The Special Committee appointed for the purpose presented a memorial of the late George B. Roberts, which, by a rising vote, was unanimously adopted:

The Tellers reported that at the election of members held on this date, seventy-six legal votes were cast, electing Messrs. Chester E. Albright, Jr., and J. B. Baker, Jr., to Active Membership, Mr. Frank T. Gucker to Junior Membership, and Mr. James B. Bonner to Associate Membership.

Upon motion by Mr. F. Schumann, it was Resolved, that a committee of five be appointed to consider the suggestions embodied in the paper presented by the President of the Club on February 20th.

Mr. Harvey Linton read a paper on "The Sewage-Disposal Plant at Altoona, Pa.," and illustrated his remarks by a series of lantern views and drawings.

STATED MEETING, March 20, 1897.—The President, Joseph T. Richards, in the chair. Sixty-seven members and visitors present.

The death, on March 7, 1897, of Mr. Isaac S. Cassin, an active member since 1881, was announced.

The Committee on new Club-House was by motion increased to eight members.

Mr. Carl Hering presented, by title, a list of distances on the nearly level asphalted streets of Philadelphia.

On behalf of the late Amasa Ely, Mr. John C. Trautwine, Jr., presented a paper on "The Construction of the Queen Lane Reservoir."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, Saturday, January 16, 1897.—Present: The President, the Vice-Presidents, Directors Leffmann, Livingston, Richards and Schermerhorn; the Secretary and the Treasurer.

The Treasurer's report for December showed:

Balance from November,	$419 50	
Received during December	608 80	
		$1,028 20
Expended during December		914 84
Balance December 31st		113 36

The Treasurer presented his Annual Report as approved by the Committee of Auditors. He stated that in the printed annual report of the Board of Directors, in which it was incorporated, it had been changed so as to make the cash balance, $48.36, instead of $113.36. The Treasurer's report was received and ordered filed. The annual report of the Board as printed was then considered.

It was resolved that the President present to the Club the annual report of the Board of Directors as printed, with the correction in the cash balance of the Treasurer above alluded to, and with the statement that the figures in the published summary of membership are incorrect, and a request that the Board be allowed to change them when the Membership Committee has made them accurate.

Resignations were presented and accepted from Lewis N. Lukens and Francis P, Smith, active members.

Mr. Hering presented the report and recommendations of the retiring Publication Committee, which were received to be referred to the incoming Publication Committee for further consideration.

ORGANIZATION MEETING of the Board of Directors, Saturday, January 23, 1897.—Present: The President, the Vice-Presidents, Directors Schermerhorn, Hartley, Eglin and Livingston, the Secretary and the Treasurer.

In accordance with the request of the Club at the Annual Meeting, and upon motion, the Board appointed Mr. C. H. Ott a Director to fill the vacancy caused by the election of Mr. Richards to the Presidency.

The President announced the following standing committees for 1897, the first named in each case being the chairman:

Finance Committee—Wm. C. L. Eglin, Max Livingston, Henry Leffmann.
Membership Committee—L. Y. Schermerhorn, G. B. Hartley, C. H. Ott.
Publication Committee—Henry Leffmann, Carl Hering, L. Y. Schermerhorn.
Library Committee—G. B. Hartley, Henry Leffmann, F. Schumann.
Information Committee—F. Schumann, L. Y. Schermerhorn, Carl Hering.
House Committee—C. H. Ott, Wm. C. L. Eglin, Max Livingston.

The Board designated the following Committees:

Regular Tellers—E. R. Keller, S. S. Evans, R. L Humphrey.
Alternate Tellers—Harrison Souder, Thos. H. Mirkil, Minford Levis.
Auditors—Jas. Christie, W. P. Dallett, H. W. Spangler.

Regular Meeting, Saturday, February 20, 1897.—Present: the President, the Vice-Presidents, Directors Livingston, Schermerhorn, Ott, Eglin, Hartley and Schumann, the Secretary and the Treasurer.

The Treasurer's Report showed:

Balance on hand, January 1st	$ 113 36	
Cash received to date	2,024 00	
		$2,137 36
Expended to date		141 44
Balance, February 20, 1897		$1,995 92

A letter was read from Mr. Minford Levis, dated February 17th, making "inquiry as to whether the advisability or desirability of officially adopting some form of certificate of membership or insignia, has at any time been considered by the Board of Directors," and further calling attention to the practice of other technical clubs, and the means by which certificates could be prepared and issued. The advantages of issuing such certificates, and the abuses that might be made of them, were both fully discussed, and upon motion, the Membership Committee was requested to consider the matter and report to the Board at its next meeting.

The Library Committee reported that a letter had been received from Mr. Gratz Mordeci, informing the Club that the estate of Thomas M. Cleemann, a former member, would be glad to present certain books, of which a list was enclosed. The Board accepted the offer, and directed the Library Committee to prepare a letter expressing its thanks, to be signed by the President. The Library Committee asked instructions as to its duties in the matter of renewing publications. Upon motion it was resolved that the standing committees be instructed to hold a general meeting at an early date, and determine their relation to each other in the disposition and arrangement of Club business and property, and to report the essential features of their agreement to the Board at its next meeting.

The Information Committee reported that a program had been arranged for four Club meetings, including the meeting of this date, and that a stenographer had been employed to report Club meetings for the balance of the year.

Regular Meeting, March 20, 1897.—Present: The President, the Vice-Presidents, Directors Livingston, Schermerhorn, Eglin, Hartley and Ott, the Secretary and the Treasurer.

The Treasurer's Report showed:

Balance cash in hand February 1st	$1,827 36	
February receipts	480 21	
		$2,307 57
Expenditures during February		136 44
Balance February 28th		2,171 13
Receipts to March 15th		180 00
		2,351 13
Expenditures		352 90
Balance on hand		$1,998 23

The Membership Committee presented a written report upon the suggestion to adopt a certificate or badge for Club membership, with the correspondence that had been obtained as to the practice of other organizations in this matter. The Committee concluded that the disadvantages to the Club by the adoption of a certificate and badge, or either, would more than outweigh any advantages that might accrue. On motion, the report was received and ordered to be filed, and the Committee was discharged.

The estimates of appropriations desired by the Publication, Library and House Committees were considered, and upon motion, requests for appropriations for standing committees were referred to the Finance Committee to consider and report to the Board at its next meeting, with statements of past expenditures and probable income.

Filter-Beds. Sewage-Disposal Plant at Altoona, Pa.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.
INCORPORATED JUNE 9, 1892.

Vol. XIV.] JULY—SEPTEMBER, 1897. [No. 2.

V.

THE SEWAGE-DISPOSAL PLANT AT ALTOONA, PA.

BY HARVEY LINTON, Active Member.

Read March 6, 1897.

THE subject of sewage disposal is one that is sure to compel attention in cities and towns that are built upon small water-courses.

Location.—An illustration of this fact is afforded by the city of Altoona, on the line of the Pennsylvania Railroad, at the base of the Allegheny Mountains, between the elevations 1,110 and 1,350 feet above the ocean, and near the headwaters of the Juniata River. From the larger part of the city the sewage and surface-water flows northeastward. A little less than half the city, for which the sewage-disposal plant is being constructed, is drained southward, towards Hollidaysburg, the county-seat of Blair County. These streams unite at Petersburg, 27.5 miles east of Altoona, forming the Juniata River.

Population.—The population of Altoona was 30,337, in 1890. By Clark's Directory-Census it was 35,500 in 1895. It is 15,000 in the Fourth Sewer District. In the suburbs, south of the city, there is an additional population of about 2,000. In the Fourth

Sewer District the population may increase to 25,000, and in the adjoining suburbs, tributory to this sewer, it will probably increase to 5,000. The sewage-disposal plant for this district should, therefore, be capable of being extended to provide for a population of 30,000.

Area.—The area of the Fourth Sewer District is about 730 acres, or $1\frac{1}{5}$ square miles. The area of the whole water-shed that is usually drained by the sewers, is 1,598 acres, or about $2\frac{1}{2}$ square miles. The sewers, not being large enough to carry off all storm water, are occasionally overflowed and the streets and low grounds submerged. From the city limit to Mill Run, a distance of 1,500 feet, there is very little, if any, flow in the stream channel except sewage, during the summer months.

Drainage Area.—At Mill Run, the drainage area is about 11 square miles. The total drainage area of all the streams at the junction of Mill Run and Sugar Run, 3 miles from the city limit, and at the end of the out-fall sewer, is 40 square miles, or 2.70 square miles per thousand of population connected with the sewer, or only 1.50 square miles per thousand of population to be considered in providing for sewage disposal.

Three and one half miles below Sugar Run, as the water flows, is the county-seat, Hollidaysburg, with a population of 3,150. The fall of the stream is about 40 feet to the mile. Opposite Hollidaysburg the stream has a much less rapid fall, and there is a dam, opposite the town, which makes slack-water for a considerable distance. Here the drainage area is 75 square miles. Some records of rainfall and stream-flow are presented, as being of interest in this connection.

Rainfall.—Comparison between the records in Altoona in 1895, from observations of Dr. Charles B. Dudley, Chemist, P. R. R. Co., and those made at the same time by the Altoona Water Department, at Kittanning Point, nearly 300 feet in elevation above the city, shows that the rainfall at the higher level was 31.584 inches, while it was only 21.17 inches in the city. Assuming that the rainfall at Kittanning Point for the past thirteen years has been 40 per cent. greater than in Altoona, the average rainfall on the 9.3 square miles from which the city obtains its water supply was 42.83 inches, while in the city it was but 30.81 inches.

Stream-flow.—The stream-flow, immediately below the old 55,-000,000 gallon reservoir, was measured three times daily, by the Water Department, from December, 1894, to March, 1896, and the amount of the daily flow is shown in connection with the rainfall statement. This flow* is what remained after taking out the city's daily supply, which is estimated at 3,000,000 gallons. In the four months, August to November, inclusive, there was no overflow from this reservoir. Weir measurements of Mill Run, also of the sewage flow at the Fourth District sewer-outfall, were made during the drought of 1895, and the results are appended in separate statements.

Sewage Pollution.—The sewage pollution of the streams between Altoona and Sugar Run has been a nuisance for many years, during the dry season.

Damage Suits.—In 1882, suit was brought against the city for sewage pollution of springs on the property of Peter Good, 11,400 feet southward from the city limit. After appealing this case to the Supreme Court, the city paid, in 1895, in interest and costs added to the original verdict of $5,000, damages, amounting to $6,555.36. Another suit was brought, in 1889, for damages for contamination of the "Big Spring," on the W. H. H. Kinsel property, 11,100 feet from the city limit. Judgment was entered against the city, in this case, in 1895, for $2,812.45. These springs are shown on the accompanying map. It is possible that sewage from the stream may reach these springs, through underground channels in the limestone.

Nothing was done by the city towards improvement of old sewage-disposal methods, except the survey and estimate herein noted, until January, 1895. It was then determined to take action, and to be guided by engineering advice.

Engineering Advice.—Mr. Rudolph Hering, a member of this Club, was called upon, and on February 4th, he visited Altoona and went over the ground of the proposed sewer and filter-beds. Mr. Hering, in his report to the City Councils, February 7, 1895, said: "Whatever may be the future mode of disposal, the sewage will first have to be carried further down the valleys. This part

* 2,046,573,000 gallons in 1895.

of the work is advised at present." It was then supposed that the dilution of the sewage, at Sugar Run and by the other streams coming in below, would prevent any complaint until a larger growth of the city would make sewage treatment necessary. The town of Hollidaysburg, however, took another view of the matter, and the prospect of further damage suits made it advisable to proceed at once to make final and satisfactory disposition of the city's sewage. Elsewhere in his report Mr. Hering said: "The best means of purifying sewage is by filtration through sand, soil, or artificially prepared materials. Natural filtration through sand is to be preferred in every case where sufficient territory can be secured for the purpose at a fair price. The sewage must be applied intermittently, so as to allow sufficient time and opportunity for oxidation of the organic matter to take place in the interstices of the sand." Different methods of sewage treatment were described and the subject was fully discussed. Mr. Hering had gone over the ground in 1888, and at that time suggested such a sewer as is now constructed to Sugar Run, and, in 1889, the writer, acting on this suggestion, made a survey and an estimate of cost for this work.

Hollidaysburg's Objections.—In November, 1895, after the construction of this sewer was begun, the people of Hollidaysburg, who objected to Altoona's sewage being discharged three miles nearer to their town, made complaint before the Court. An injunction was soon granted, which still restrains the city from making any use of the sewer until after the construction and successful operation of the filter-beds.

Capacity of Outfall Sewer.—This sewer is capable of carrying nearly 27 cubic feet of water per second, from the Fourth District sewer; or 17,230,000 gallons daily.

The contract for its construction was awarded to Messrs. Campbell & Dennis, of Joliet, Ill., September 7, 1895. The work was completed August 7, 1896, at a cost of $42,912.49. Five per cent. of this amount is retained until the contractor shall make the sewer practically impervious to ground-water. During construction, small openings were left in the bottom of the sewer, to allow the ground-water to flow through, at a few places, where it was troublesome. The contractor was given the choice between

this method, with its necessary pumping, and laying an underdrain. At this writing, February 18th, considerable progress has been made in calking this sewer, with oakum and Portland cement.

Ground-Water in Sewer.—Weirings of the flow in the sewer, taken December 15 and 16, 1886, showing the extent of the leakage, are here given.

Tests of Sand for Filtration.—In August, 1895, test-pits were dug on the site of the proposed filter-beds to the ground-water level, which was from six to nine feet below the surface, and samples of the soils were taken from these pits by Mr. Allen Hazen, Consulting Engineer.

Mr. Hazen's report to the Committee on Sewage Disposal, November 22, 1895, says: "The material of this land is made up of two distinct layers. The upper layer is from one to five feet in depth in different parts of the field and consists of a fine, sandy soil or loam with fine sand below. The upper part or soil differs from the lower part of the layer only in containing more organic matter, and the difference is not great enough to warrant any subdivision of the material in handling it. The material allows water to percolate through it somewhat freely, but it contains a considerable amount of iron and alumina, as is shown in the chemical analyses appended to this report, and these and other gelatinous materials allow it to be compacted more closely than pure sand and to cake together into a solid mass upon drying after having been wet. The second kind of material underlies the upper layer, and is much more open in its texture, and consists of particles ranging all the way from moderately fine sand to bowlders a foot in diameter."

Diagram of Mechanical Analysis.—A diagram, showing the percentages, by weight, of these filtering materials, of different diameters of grains, was prepared by Mr. Hazen. See page 90.

Capacity of Filtration Plant.—These filter beds must provide for about 750,000 gallons of sewage per day, at present, estimating 50 gallons per capita daily from a population of 15,000. This does not include rain-water or ground-water. There are no large manufacturing establishments, and little but domestic sewage is discharged into the sewers. A considerable part of this population of 15,000 is not directly connected with the sewers.

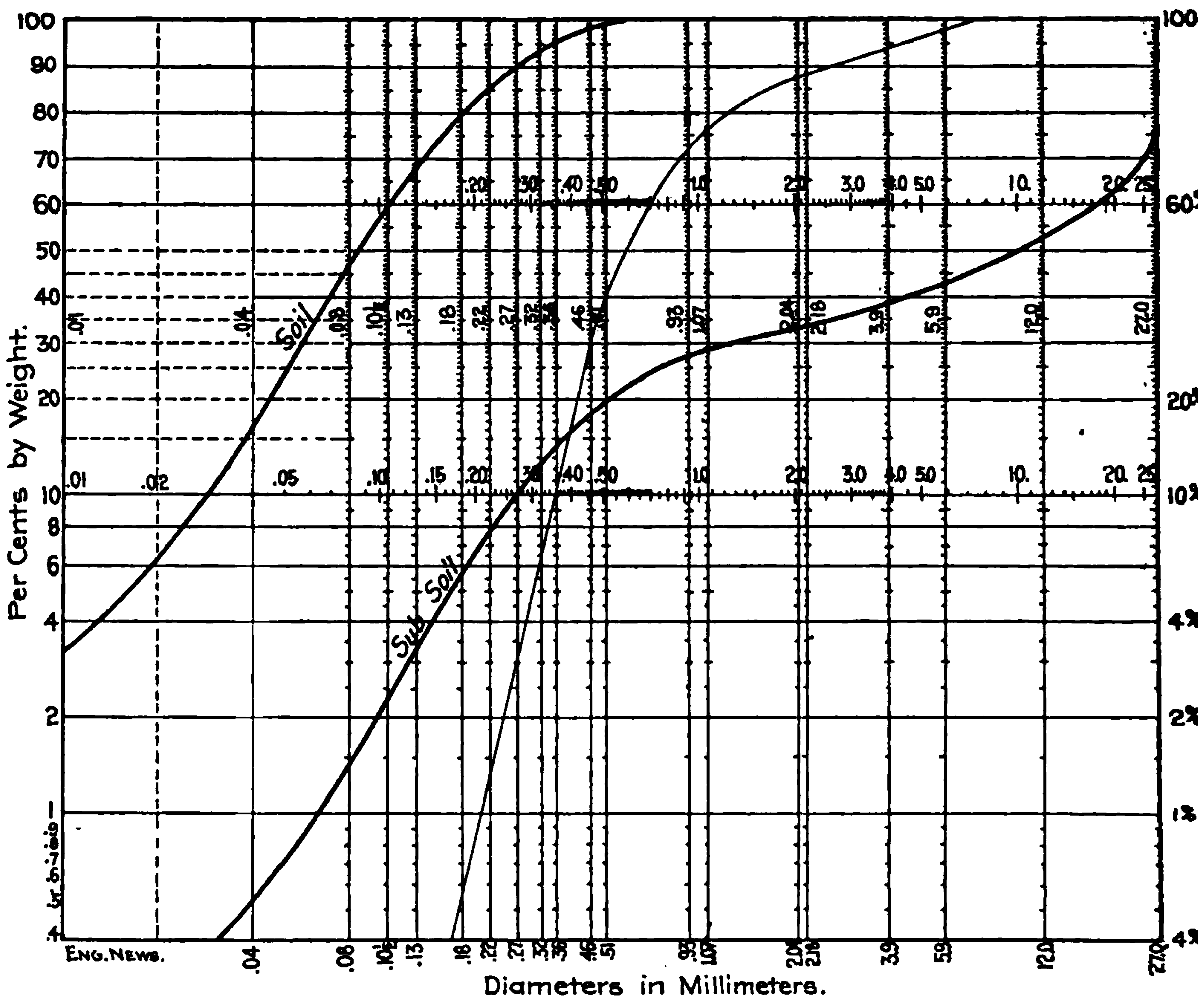


Diagram of Mechanical Analysis of Soil. Prepared by Allen Hazen, C. E.

Loaned by The Engineering News Publishing Company.

Corn will be planted on the filter beds this year if the work of grading is completed in time.

Cost of Land.—The City purchased from the Burns' Estate $95\frac{9}{10}$ acres of land, February 21, 1896, for $12,000. Of this area nearly 70 acres are available to be graded for sewage-beds.

Underdrains Contract.—The contract for laying a system of underdrains, of agricultural drain tiles and terra-cotta sewer-pipe, was awarded to Mr. M. V. Orner, April 3, 1896. These underdrains are from four to six feet below the level of the proposed filter-beds. The work under this contract was finished August 4, 1896, at a cost of $5,438.86. Details of this work are shown in appended statements.

Filter-Beds Contract.—The contract for the grading of the filter beds, the construction of the 18-inch pipe sewer from the outfall sewer at Sugar Run, 1,439 feet southward, the 16-inch iron siphon under the river, the screen tank, sewage carriers, 10-inch siphon, gate chambers, etc., was awarded to Mr. Wm. H. Herr, August 7, 1896. There has been expended upon this work $7,522.50. The principal work remaining to be done is the grading of the sewage-beds. It is intended that these filter beds shall be completed and in operation by June, 1897.

Specifications.—The specifications, a copy of which is presented with this paper, are largely the work of Mr. Hazen. They contain much information that must be omitted from a paper to be read in one evening.

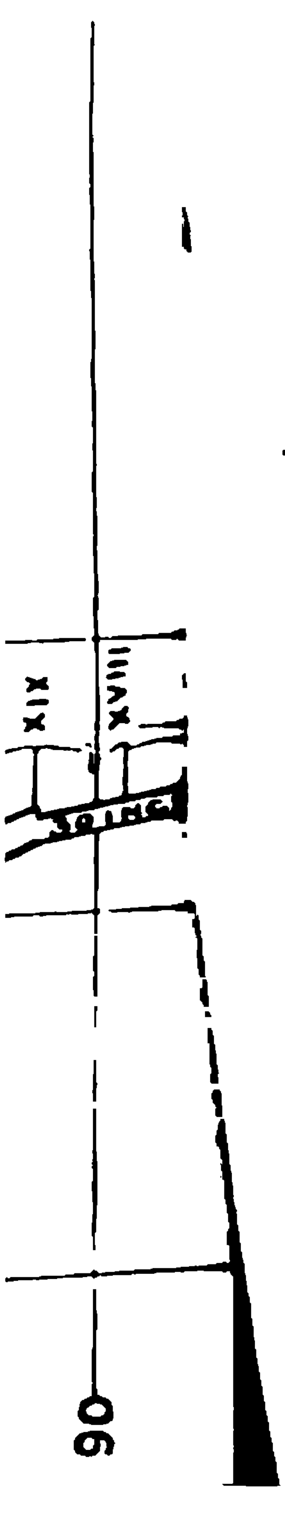
Cement.—American Portland cement was used in all masonry and sewer work. Seven-day tests, for tensile strength, of neat cement were made from samples taken from the cars or warehouse, and the use of any lot of cement before its acceptance was prohibited. There is, sometimes, difficulty in enforcing this provision of the specifications. The cement that is satisfactory becomes scarce, and in order not to delay construction, various substitutes are allowed to be used after one-day tests. It would be better policy for the city to purchase all cement and to furnish it to the contractor as required.

Concrete Sewer.—The construction of a $33\frac{1}{2}'' \times 44''$ brick sewer, one brick, or four inches, in thickness, strengthened by from four to six or eight inches of concrete, was accomplished without diffi-

culty by the use of forms shown. The invert is made of vitrified shale paving brick. The cost of such a sewer is less than that of a two-ring, (8½ inches) brick sewer of the same size. Under Burgoon's Run, the sewer was protected by extra thickness of concrete on both sides, and by rubble masonry. The 27-inch pipe-sewer, under Mill Run, is encased in concrete from bottom to top, twelve inches on each side more than the diameter of the pipe, and nine inches above the top; 1½ inches of mortar; one part cement to one part sand; was laid on the top, before the concrete was set.

Cross-Section of Brick and Concrete Intercepting-Sewer.

Intake.—The intake opening is made through the eastern wall at the outfall of the Fourth District sewer, and its center is 13.3 feet from the end of the sewer, which is near the city line. A dam six feet long is built upon the rock bottom and between the two walls at the sewer outfall, to an elevation of one foot above the top of the intake opening. This dam will divert the ordinary flow of the sewer and rainfall flow, amounting to 27 cubic feet per second, into the 27-inch outfall sewer. The intake is guarded by fourteen iron bars, ⅝ inch x 4 inches and 10 to 11½

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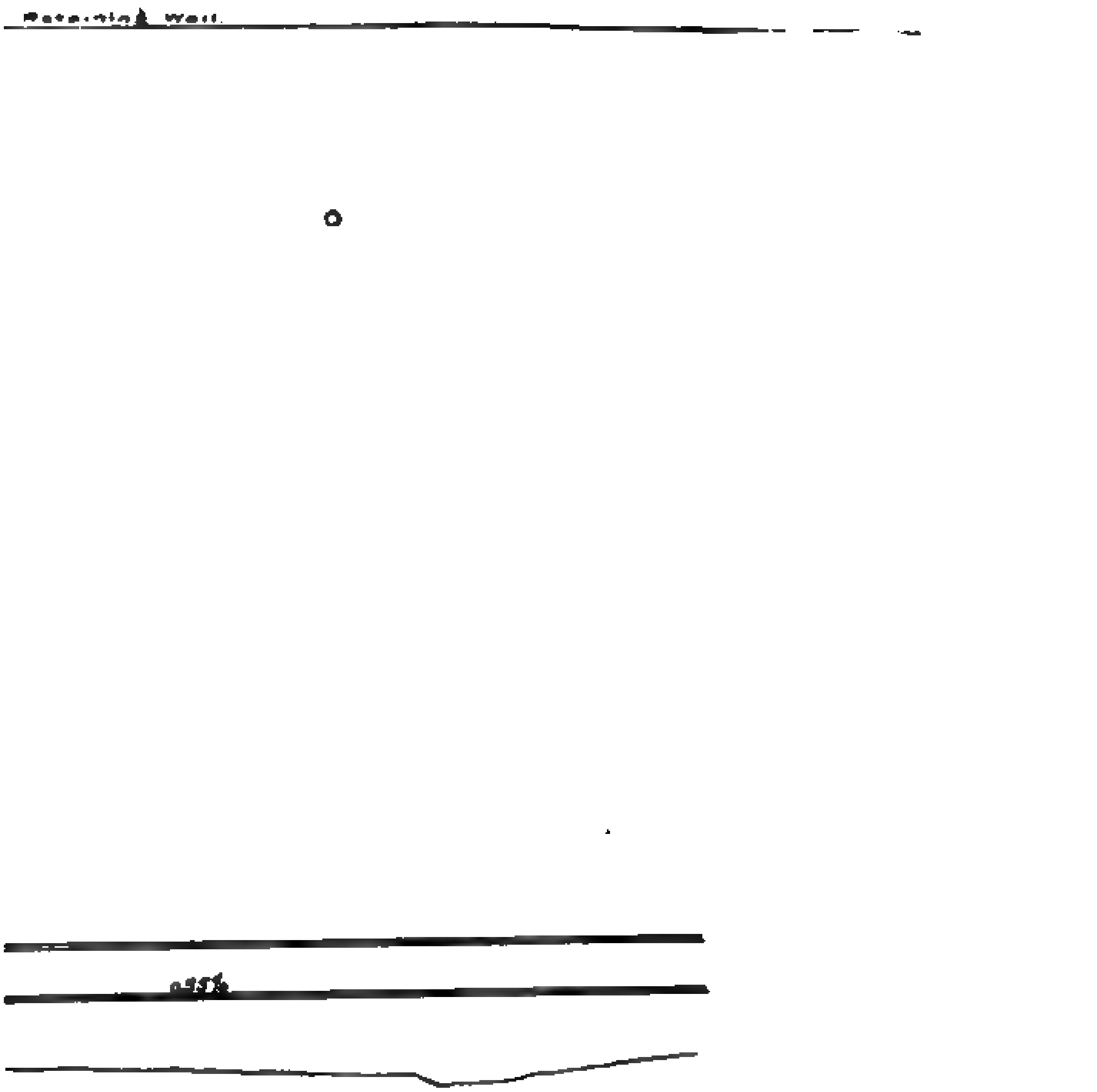


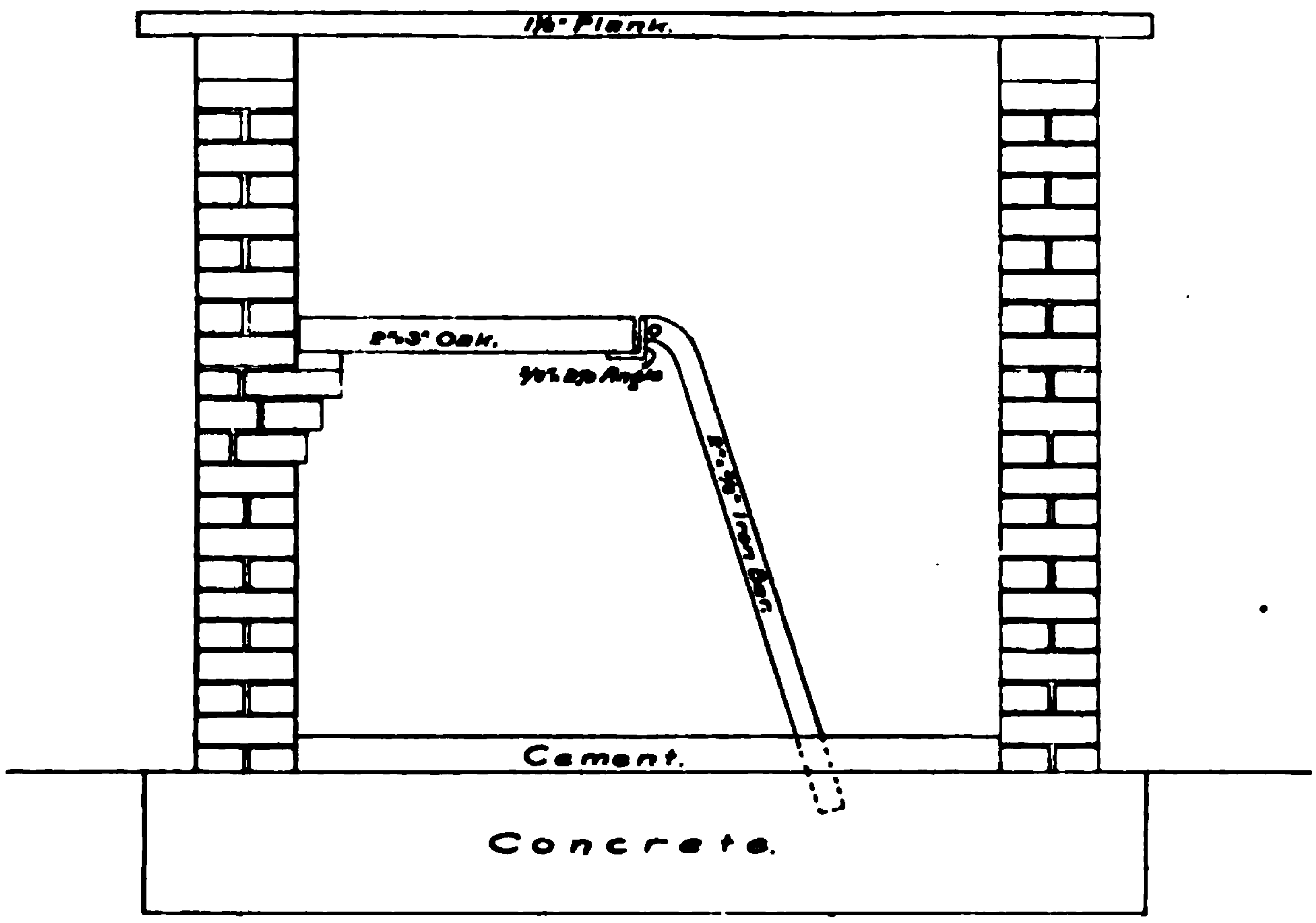
ALTOONA SEWAGE DISPOSAL PLANT.

Profile of Ten Inch Iron Siphon

feet long, set 5 inches apart from center to center, so as to offer the least obstruction to the flood-water.

Manholes.—Manholes, generally, are oval, 3½′ x 4½′, in plan at the top of the sewer. The bottom of each manhole is made to conform to the grade and shape of the sewer. Perforated manhole covers, and frames of the pattern used in Providence, R. I., are used.

It is intended that these manholes shall be used for sewer con-



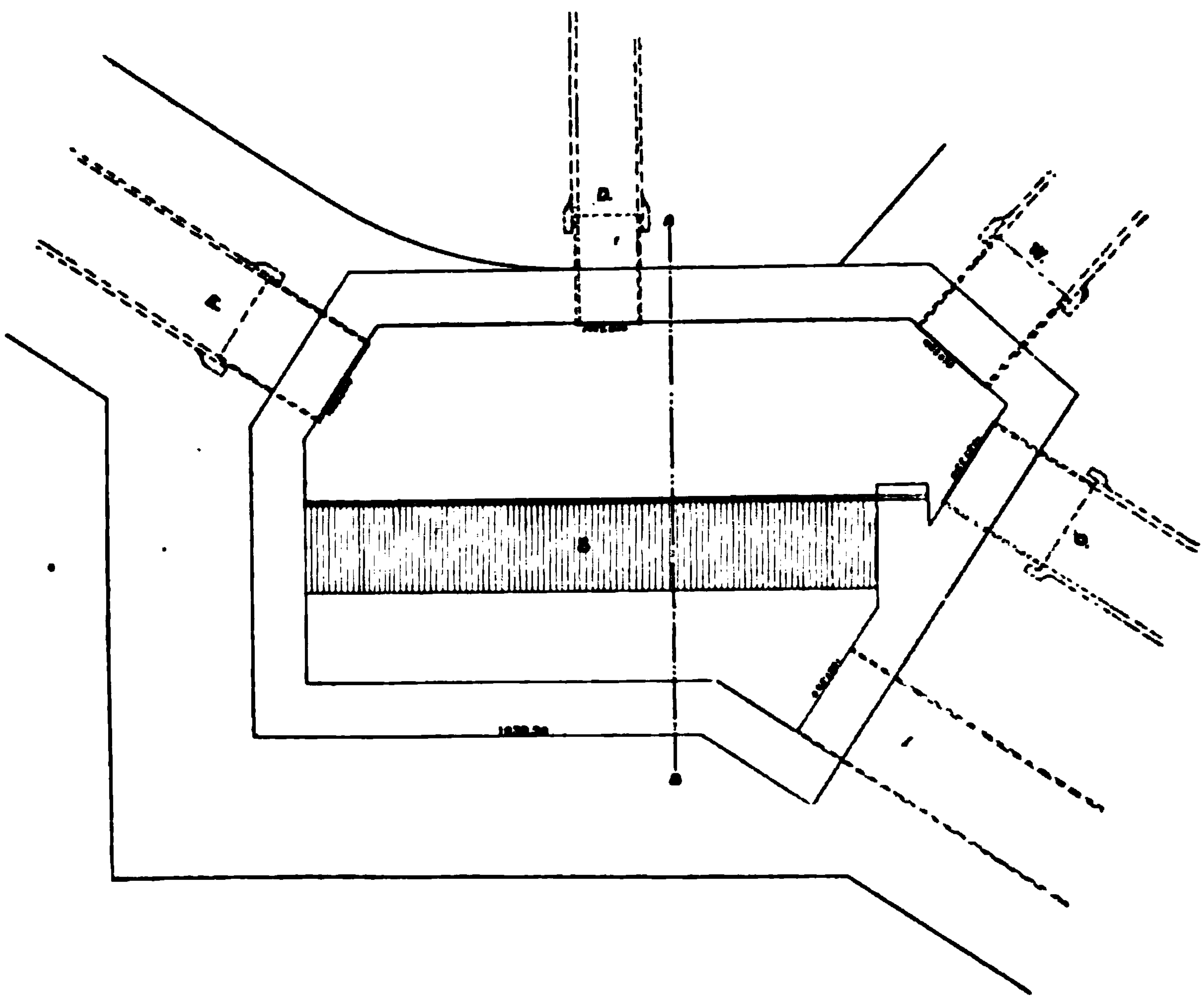
ALTOONA SEWAGE DISPOSAL PLANT.
Section of Screen Tank

nections for the towns of Millville, Allegheny and Westmont, on Mill Run; with a population of 1100; and for Llyswen, if City Councils will grant permission to these towns for such use of the sewer.

Special Manhole.—At Sugar Run, an 18-inch sewer will carry the sewage from the larger brick sewer towards the filter beds. In a special manhole shown in Fig. 3, a dam will be built of sufficient height to divert the sewage flow into the 18-inch pipe. When there is an excess of water in the larger sewer it will over-

flow the dam and be discharged at the junction of Mill Run and Sugar Run. A sluice gate in this manhole, at the opening for the 18-inch sewer, will allow the shutting off of all flow through it in time of heavy rainfall, and a 15-inch gate in the dam being opened (and in such a manner that it will be out of the way of the storm-water flow), will prevent the accumulation of sand and gravel in the manhole and sewer.

Screen Tank.—The screen tank is provided with a screen, 8



PLAN OF SCREEN TANK.

feet long, of ¼″ x 2″ x 45″ iron bars, set edgewise to the flow, and one inch apart from center to center. The lower ends of these bars are imbedded in the concrete bottom. A wooden grating platform, 2.5′ x 8′ is fixed 3 feet above the bottom, upon which the solid matter, raked from the grate, may drain before it is thrown out to be burned or otherwise disposed of. A simple form of cast-iron gate serves to direct the flow of sewage. These gates, of 10, 12 and 15 inches diameter, are also used in the gate-

chambers. All of these structures are built of brick upon concrete bottoms, 12 inches in thickness. The walls are finished with vitrified paving brick set on edge, in 1 to 1 Portland cement mortar, for coping.

Owing to the fact that for all of the work herein described cash was to be paid, on monthly estimates, the money having been secured by the sale of bonds by the city, the bidding, when the contracts were to be awarded, was lively. Contracts were awarded to the lowest bidders, and in every case for less than the engineer's estimate. In the case of the out-fall sewer, it was so evident that the lowest bidder must suffer considerable loss that the writer called the attention of the Committee on Sewage Disposal to the fact. The Committee, however, felt bound to accept the lowest bid. The contractor showed that he was fully responsible and he complied with the requirements as to furnishing bonds, etc. He also proved that he had had large experience in sewer-work. Notwithstanding the loss he was obliged to suffer—even with the favorable conditions of lower prices, generally, for materials and labor than were anticipated—the work was done by the contractor, on the whole, conscientiously. One exception to be noted in the general good quality of the work is the result of the employment of unskilled labor. Among the pipe-layers and bricklayers there were those who would not or could not make water-tight joints, as the specifications require. The closest and most constant inspection, and such as was not provided, would hardly have made water-tight work, without good workmen. The contractor is now remedying this defect in the sewer.

Tables of Bids Received.—Tabulated statements of all bids received are appended; also, a general map and profile view of the sewer, and the eastern sewage-carrier in the filter bed, and plans and profiles of some of the details of the work

RAINFALL, in 1895–1896.

FROM RECORDS

of Dr. Chas. B. Dudley, at Altoona, Pa.		of Altoona Water Dep't, at Kittanning, Pa.
MONTH.	INCHES	INCHES.
Jan'y, 1895,	3.22	3.758
Feb'y, 1895.	0 17	0.613
March, 1895,	1.05	1.836
April, 1895,	2.16	3.666
May, 1895,	0.80	1.713
June, 1895,	3.75	5.178
July, 1895,	1.75	3.144
Aug., 1895,	1.64	2.982
Sept., 1895,	2.28	2.854
Oct., 1895,	0.55	1.318
Nov., 1895,	1.30	1.320
Dec., 1895,	2.50	3.202
	21.17	31.584
Jan'y, 1896,	0.87	0.750
Feb'y, 1896,	1.94	1.238
March, 1896,	1.77	1.681
April, 1896,	1.38	2.057
May, 1896,	2.70	3.974
June, 1896,	7.69	8.079
July, 1896,	4.22	5.958
Aug., 1896,	1.70	2.524
Sept., 1896,	6.03	7.098
Oct., 1896,	1.66	2.630
Nov., 1896,	2 59	3.323
Dec., 1896,	0 89	1.722
	33.44	41.034

STREAM-FLOW

at Kittanning Point. From Weir Measurements (9.8 Sq. Miles Watershed).

	GALLONS PER 24 HOURS.
Dec., 1894	270,927,500
Jan'y, 1895	341,908,000
Feb'y, 1895	65,599,000
March, 1895	662,386,000
April, 1895	836,541,500
May, 1895	93,397,500
June, 1895	14,951,000
July, 1895	12,279,500
Aug., 1895	No flow.
Sept., 1895	" "
Oct., 1895	" "
Nov., 1895	" "
Dec., 1895	19,510,500
	2 046,573,000
Jan'y, 1896	26,008,000
Feb'y, 1896	338,844,000
March, 1896	482,732,500
April, 1896	
May, 1896	
June, 1896	
July, 1896	
Aug., 1896	
Sept., 1896	
Oct., 1886	
Nov., 1896	
Dec., 1896	

Weir Measurements made below 55,000,000-gallon Reservoir, supplying the City of Altoona 3,000,000 gallons daily.

ANNUAL RAINFALL

FOR THIRTEEN YEARS.

At Altoona, Pa., as observed by Dr. Chas. B. Dudley.		At Kittanning Point; 300 feet higher than Altoona.		REMARKS.
		40% greater than at Altoona.	Actual Measurements.	
1884............	28.18 inches	39.45 inches		Assuming that the rainfall at Kittanning Point is 40 per cent. greater than at Altoona.
1885............	18.90 "	26.46 "		
1886............	30.86 "	43.20 "		
1887............	25.88 "	36.23 "		
1888............	33.62 "	47.07		
1889............	37.03 "	51.84		
1890............	41.99 "	58.79		
1891............	37.84 "	52.98		
1892............	29.50 "	41.30		
1893............	30.62 "	42.87		
1894............	31.55 "	44.17		
1895............	21.17 "	29.63 inches	inches 31.58	Actual Measurem't, 49.2%
1896............	33.44 "	46 82 "	41.03	" " 23.0% greater than at Altona.
Average....	30.81 inches	43.13 inches		

FINAL ESTIMATE, August 7, 1896,

of Cost of Sewer between Altoona and Sugar Run.

Campbell & Dennis, Contractors, Joliet, Ill.

5,774	lin. ft. excav. and B. F. for brick sewer,	@	$0.60	$ 3,464 40	
3,110	" " " " " " 30″ pipe sewer,	"	.25	777 50	
6,083	" " " " " " 27″ " "	"	.20	1,216 60	
167	cu. yds. excav. for masonry, etc...........	"	.50	83 50	$ 5,542 00
5,774	lin. ft. brick sewer, 33½″ x 44″............	"	1.50	8,661 00	
3,110	" " pipe sewer, 30″......................	"	2.50	7,775 00	
6,083	" " " " 27″........................	"	2.00	12,166 00	
32	manholes....................................	"	25.00	800 00	29,402 00
1,173.3	cu. yds. concrete masonry....................	"	5.00	5,891 50	
44	" " rubble "	"	6.00	264 00	
9.2	" " riprap "	"	3.00	27 60	6,183 10
	Rock excavation (force acc't)........			....	984 94
	Intake, complete..			....	200 00
	Extra work and bills..			....	600 45
					$42,912.49

FINAL ESTIMATE, August 4, 1896,

of Cost of System of Underdrains for Sewage-beds at Creswell Station, four miles south of Altoona, Pa.

M. V. Orner, Contractor.

12 feet 15-inch iron pipe.......................................@	$1.55	$ 18 60
24 " 10 " " " ...."	0.75	18 00
60 " 6 " " " ...."	0.46	27 60
186 " 15 " terra-cotta pipe......................................"	0.52	96 72
405 " 12 " " " ...."	0.39	157 95
715 " 10 " " " ...."	0.33	235 95
695 " 8 " " " ...."	0.27	187 65
1,202 " 6 " tile underdrains......................................"	0.18	216 36
10,952 " 5 " " " ...."	0.17,	1,861 84
9,795 " 4 " " " ...."	0.165	1,616 18
5,515 " 3 " " " ...."	0.155	854 89
Add 16.12 per cent. of $443.69 for extra excavation in Division "C" of filter-beds.......................................		71 52
Add 151.2 cubic yards excavation in water..........................@	0.50	75 60
		$5,438 86

WEIR MEASUREMENTS OF FLOW OF SEWAGE

At the Fourth District Sewer Outfall, Altoona, Pa., in October, 1895.

(From September 28th, to December 20th, 1895, 84 days, the water-supply of the city was cut off, except between the hours of 4 and 8 P.M.)

1896	Hour.	Depth of Flow at Weir.	FLOW.		REMARKS.
			Cubic feet per Second.	Gallons per 24 hours.	
Oct. 4	7.10 P.M.	0.156 ft.	0.816	527,350	Weir, 4 feet wide.
" 5	7.12 "	0.135 "	0.660	426,539	
" 7	5.45 "	0.125 "	0.588	380,008	
" 8	5.25 "	0.135 "	0.660	426,539	
" 9	6.15 "	0.146 "	0.741	478,888	
" 10	2.45 "	0.060 "	0.222	143,472	Water supply cut off.
" 11	6.40 "	0.170 "	0.8653	559,240	
" 12	6.07 "	0.156 "	0.816	527,350	

Extreme Dry-Weather Flow of Sugar Run and Mill Run at End of Sewer. Lowest for Many Years.

1895			C. f. s.	Gallons per 24 hours.	REMARKS.
Nov. 8			0.96	621,930	Sugar Run.
Nov. 11			1.12	728,957	Mill Run.
			2.08	1,350,887	Little Juniata River.

WEIR MEASUREMENT

Of Flow of Ground-Water in the Outfall-Sewer Between Altoona and Sugar Run. Twelve-inch weir, with contractions.

Time—1896.	Manhole No.	Station.	Depth on Weir, feet.	Cubic feet per Second.	Gallons per 24 hours.
Dec. 16	I	4 + 50	.0	.0	
" 16	III	12 + 93	.0	.0	
" 16	IV	16 + 75	.072	.065	42,010
" 15	IX	40 + 34	.075	.068	43,950
" 15	XIII	61 + 09	.078	.073	47,181
" 15	XV	73 + 98	.097	.100	64,631
" 15	XIX	93	.130	.154	99,533
" 15	XXII	98	.130	.154	99,533
" 15	XXV	108 + 97	.190	.269	173,859
" 15	XXVII	119 + 32	.199	.288	186,139
" 15	XXIX	127 + 93	.231	.356	230,620
" 15	XXX	133	.231	.356	230,620
" 15	XXXI	137 + 88	.268	.448	289,386
" 15	XXXII	143 + 29	.307	.544	351,875

Station 150 + 73 is at the outfall at Sugar Run.

8

DISCUSSION.

MR. ALLEN HAZEN (Visitor; Boston).—I do not think that the diagram which Mr. Linton has shown needs much explanation. We found at Lawrence a long time ago that the action of filtering materials depends more upon the sizes of the particles composing them than upon any other condition. The sizes of the particles in various materials were measured, and the diagram is reproduced from one of the sheets in use for recording the results of such examinations. The vertical lines represent the separations which are used. The coarser ones represent sieves. For instance, the line marked .27 represents a sieve which allows particles smaller than .27 millimeter to pass, and retains larger particles. The separations less than a tenth of a millimeter represent beaker elutriations. The horizontal lines show the percentages by weight, and the curve representing the analysis of a material drawn on this sheet shows at once the percentage by weight of particles finer than any given size.

You will notice that the soil is considerably finer than the subsoil. The upward bend in the subsoil curve toward the upper end is due, I think, not to any such actual curve in the material as a whole, but to the fact that particles larger than an inch and a half or two inches in diameter were not included in the samples, and are, therefore, not represented in this plotting. You will notice the light line which is lithographed on the sheet and represents the average of analyses of about one hundred sands used in European water filtration, and is put upon the sheets as a standard of comparison, particularly for sands for use in water filtration. In sewage purification a much wider range of materials can be satisfactorily used than are suitable for water purification.

An inverted syphon similar to the one at Altoona has been used at Gardner, Mass., for a number of years. The sewage has but a slight velocity through it, and the heavier matters from the sewage are deposited at the bottom of the pipe until they nearly fill it and block the passage of the sewage. The sewage then backs up for a few feet until it acquires a sufficient pressure to force the accumulation out, as it does at once. This clogging

and cleaning takes place regularly, without trouble, at moderately short intervals.

THE PRESIDENT.—I am glad to hear you used American materials throughout the work.

MR. RAYMOND W. SMITH.—Was the sewage still discharged into the stream? Would not that be objectionable?

MR. LINTON.—The sewage is carried down to the junction of Mill Run and Sugar Run, to about 3 miles from the city, where there is 40 square miles of drainage area. During a storm the waters are away up and I do not think you would find any trace of sewage. At the city line there is a drainage area of 2½ square miles. The greater part of this area is outside the city limits. Whenever there is much rainfall a flood of water comes down and fills to overflowing the sewers and carries everything before it. It would be impossible at this time to take care of all the storm waterflow by building storm sewers. We have not a separate system of sewerage over all the city. Some time in the future the city will cut off the sewage carriers into a separate system and leave the old sewers to carry off the storm water.

MR. SMITH.—One more question. You speak of stopping the leak in the brick sewers with oakum and cement. I would like to know to what degree that does stop the leaks and how long they will stay stopped.

MR. LINTON.—It depends upon how the workmen do the work. I have reports from the parties doing the work that they are succeeding. It takes a good deal of work. They wet the oakum and put in the cement and oakum with thin chisels until the flow is stopped. They say it stays, as far as they have gone. The contractor objected to doing this work, and was likely to give us some trouble. In order to settle the question I offered to do the work and guarantee it done satisfactorily for $200, and if it cost any more the city should pay it, and to this proposition the Committee on Sewage Disposal gave its approval. The contractor decided to go ahead and do it himself, and he is trying faithfully to do the work. The leaks must be stopped at all hazards. It is certainly possible to do it.

MR. D. A. HEGARTY.—I would like to ask a question about those screens. How many are there?

MR. LINTON.—There is one screen only, about 8 feet long.

MR. L. Y. SCHERMERHORN.—You refer to a difference of about 50 per cent. in the rainfall. How far are the gauges laterally separated from each other?

MR. LINTON.—About 5 miles. It (the difference in rainfall) was 49 per cent. in 1895, and in 1896 only 23 per cent. In both cases the higher gauge gives the greater amount.

MR. SCHERMERHORN.—I would like to know how high are the banks that separated the sewage and the sewage beds?

MR. LINTON.—The outside banks are all about 3 feet above the beds, the inside banks separating the higher beds from the next lower. The elevation of these embankments is about one foot above the level of the higher bed, with the exception of some beds which will probably have 3-feet banks. The majority are about 1 foot, excepting the outside banks, which are 3 feet.

MR. SCHERMERHORN.—You refer to a tile drain about 2 feet below the bottom of the creek.

MR. LINTON.—The tile drains are not laid anywhere less than 4 feet in depth. In the filter bed " C," after we cross the stream, we found that by draining it all out at one point we could get lower down. In doing it we got 2 feet below the bed of the stream.

MR. SMITH.—Then how do you dispose of it through the tile drains?

MR. LINTON.—The tile drain has a fall of $\frac{5}{10}$ per cent. to $\frac{6}{10}$ per cent. and the stream 2 to 3 or 4 feet per 100 feet. The stream is above the level of the beds, above the outlet of the drains, but the outlet is above the stream surface. It was an experiment. I was afraid the water would come in from the stream through the ground and fill up the tile drains, but it did not.

MR. HARRISON SOUDERS.—The following data from the report of Sr. Emilio R. Coni, to the Public Works Commission of Buenos Ayres, will be interesting in connection with the subject of sewage disposal. It was published in the *Anales de la Sociedad Cientific Argentina*, in June, 1896.

At Gennevilliers, near Paris, there is an area of 776 hectares (1917 acres) irrigated with the sewage from Paris. Of these only 6 hectares (about 15 acres) are owned by the municipality. The

rest of the area belongs to private parties who receive the sewage when they ask for it.

The sewage is distributed by a network of concrete conduits varying in size from 1.25 m. (about 4′ 1″) diameter to 0.3 m. (about 12″) diameter. The most of it being from 0.45 m. (18″) to (2′) diameter.

The total length is about 31 miles, of which 3 miles are open conduits. The conduits are generally built under the roads and lanes of the districts. Distributing valves are placed in the conduits where required.

The district is divided into three zones, which are irrigated in turn; three foremen and twenty-three helpers looking after the distribution.

Of the 6 hectares owned by the city, about 4 are rented out at 600 frs. ($120) per hectare per annum. ($48 per acre.)

The remaining two are used in carrying on experiments in irrigation and filtration.

In 1893 a total of 33,421,299 cubic meters of sewage was distributed; an average of 43,000 cubic meters per hectare, equal to 615,000 cubic feet per acre, at a cost to the city of about twelve cents per 1,000 cubic feet. The land at Gennevilliers is composed of sand and gravel of good quality and is underdrained, there being five principal drainage pipes discharging into the Seine River. The effluent is limpid, fresh and entirely free from organic nitrogen and very poor in microbes.

On the land treated as above are raised young trees and plants, alfalfa and such vegetables as cabbage, potatoes, celery, beets, onions, etc.

Mr. Rudolph Hering.—In reference to the inverted syphon by which you took the sewage, did I understand it was 16 inches in diameter, and the sewer discharge into it 18 inches? How full is the 18-inch sewer supposed to run usually?

Mr. Linton.—It has not been in operation yet.

Mr. Hering.—Is it half full, or do you expect it to run anything like that?

Mr. Linton.—Nearly full.

Mr. Hering.—A trouble which occurs so much with inverted syphons carrying sewage, is that they are likely to fill up, and

that is influenced by the velocity. A good deal of care should therefore be exercised in sizes. A difference of 16 to 18 inches, strikes me as being very little. I was merely inquiring whether that question had been considered, and whether the calculation showed that the syphon would not prove a failure, as it has done in other places. It is usual to make it much smaller and put in several pipes so that the sewage can go through one first, and if there is much of it, overflow into another and so on, that we maintain the velocity and scour out the syphons at the same time.

Mr. LINTON.—In order to make it go fast enough we carried the grade 33 per cent. to the end of the syphon, and there dropped it 1 foot.

MR. HERING.—The syphon below is run full, of course?

MR. LINTON.—The velocity will be governed by the quantity of sewage running through the 18-inch sewer, and not by the grade. We may not have gone into that subject as carefully as other parts of the work were considered.

MR. HERING.—It is very necessary to keep those syphons clear.

VI.

THE METHODS AND THE RESULTS OF EXPERIMENTS FOR THE DETERMINATION OF THE VELOCITY OF THE FLOW OF WATER, UNDER DIRECTION OF THE BUREAU OF SURVEYS, CITY OF PHILADELPHIA.

By Charles Jacobsen, C.E., Active Member.

Read, April 3, 1897.

The scientific design of sewers, especially as to their proper size, is being conducted upon more practical ideas than formerly.

In order to determine the size of a sewer, the former practice was, that, for every acre of land drained, the sewer was calculated to carry off one cubic foot of water per second. Later, Mr. Rudolph Hering introduced the Burkli Ziegler formula for the amount of rainfall which would reach the sewer.

The quantity of the discharge is expressed in a very simple formula, viz.:

$Q = a\,v.$ where

$Q =$ quantity of discharge.

$a =$ area of water section.

$v =$ velocity of flow of water.

The area of the water section being known, it is very essential that the velocity of the flow of water should be ascertained as accurately as possible. This, at present, is determined from formulas depending largely upon the judgment of the Engineer.

Mr. George S. Webster, Chief Engineer of the Bureau of Surveys, and Mr. George E. Datesman, his principal assistant, recognizing this fact and desiring to obtain practical data on this subject, caused these investigations to be commenced by the Bureau of Surveys, under direction of the writer.

In order to determine, in a practical manner, the relative percentage of the amount of rainfall which would reach the sewer, several pluviometers or rain-gauges and automatic registering stream-gauges have been placed in different parts of the city.

Observations with these instruments have been taken, computations made, and although this work is still in its infancy, enough has been established to warrant their continuance for further investigations.

It was an early practice to use floats principally to determine the velocity of the flow of water in rivers and streams, which was, of course, very unreliable, inasmuch as they were affected by local conditions. In smaller streams and canals, "Pitot tubes" and Waltman tachometers" have been used with some success (J. T. Fanning's treatise on "Water Supply, etc.," page 322). In rivers and streams where the discharge is more essential than the actual velocity, weirs are used. This is sometimes impracticable and, outside of small channels, expensive; besides, these weirs would have to be built to certain standard measurements, in order to apply the empirical formulas in use for such measurements.

Current-Meters.

These difficulties led to the introduction of the current-meters, which may be divided into two classes, namely: Cup-wheel meters and propeller-wheel meters.

The cup-wheel meters can be used with or without the electric register, *i. e.*, they are either direct-recording meters or, as the Ellis and Price meters, are provided with electric attachment.

While the former type is convenient in some cases, as the operator is not annoyed with electric batteries and connections, it is, nevertheless, unreliable.

It must be held perfectly vertical, as the least tilt in a horizontal direction causes an increased velocity. In swift streams, this is extremely difficult, the force of water tending to pull the meter down stream, thereby inclining it to the horizontal. Mr. E. E. Haskell says that in the spring of 1885, while in the employ of the U. S. Coast and Geodetic Survey, he made several experiments with this type of meter, at various angles, and obtained the results as given on Table A.

At first sight these results may seem astounding, but, considering the matter, it is plain we get what should be expected. By tilting the meter, the area and form of the wheel presented to current pressure is changed, which naturally changes the rating equa-

tion. This led to the introduction of the propeller type of wheel-meter. If the writer has been correctly informed, the only propeller-wheel meters in use are the Fteley and Stearns, the Clemens Herschel, the Hall, and the Haskell.

Of these the Bureau of Surveys adopted the latter type for its experiments, and has two sizes; the smaller being used only in small egg-shaped sewers and pipes.

In this type of wheel we find that, by tilting it at the extreme angle of 20 degrees, the results will be only 2 per cent. or 3 per cent. less than when horizontal. In the larger size, the wheels

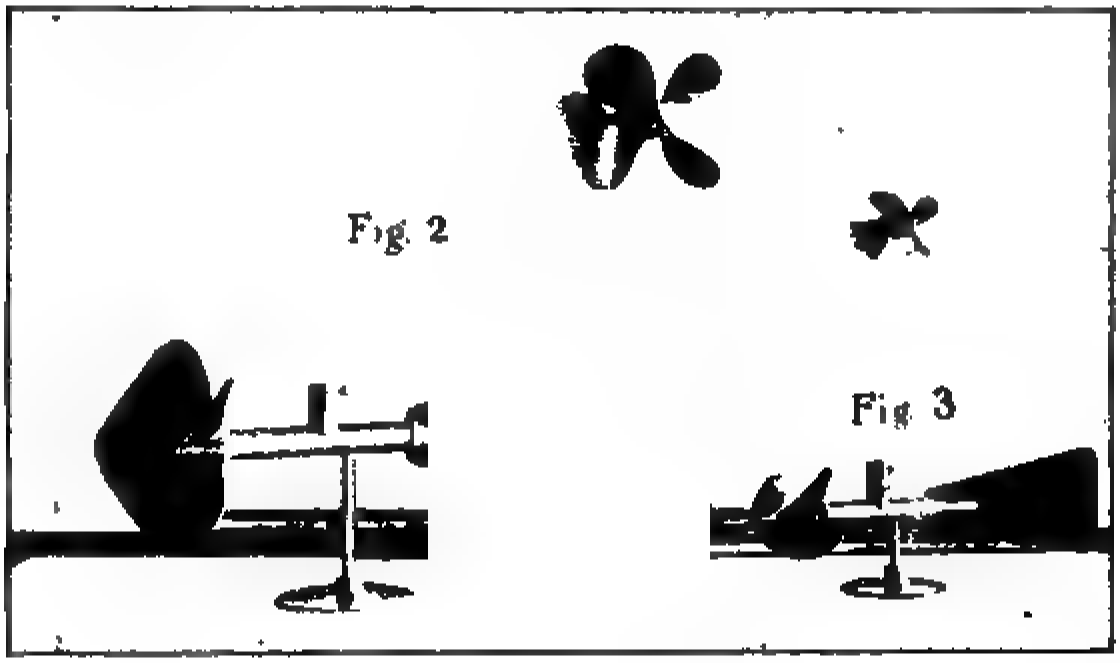
Angle of meter with the horizontal.	Time in seconds of going the length of a course 300 ft. long.	Number of revolutions of wheel.	Increase by being tilted.
0° 5°	100 100	70 78	8 rev. or 12%
0° 10°	128 126	68 79	11 rev or 17%
0° 15°	76 76	70 84	14 rev. or 20%
0° 15°	111 111	68 82	14 rev. or 21%
0° 20°	90 90	69 86	17 rev or 25%
0° 20°	354 354	58 73	15 rev or 26%

TABLE A.

are 7½ inches in diameter, and in the smaller they are 4 inches in diameter. (See Figs. 2 and 3).

These meters have each two revolving wheels of the same diameter, but the flukes have different pitch, one somewhat greater than the other, for use in different currents of water, and are known as the low-pitch and the high-pitch wheels. The internal diameters are also alike and either wheel can be used upon the supporting axis or pin. In the center of the upper part of the meter can be attached a hollow rod, through which the insulated wire passes for connection. To the lower part, a foot is

attached to prevent the meter from being sunk into mud, or struck against stones in the bottom of the streams. The connection with the revolving wheel is made through a contact spring-pin, which constantly presses against the wheel-bearing, the latter having inserted in it a washer composed of two sections, one-half metal and one-half hard rubber. Therefore, when the wheel revolves, as soon as the contact-pin enters the metal section, the register will commence to move, the current being closed, and ceases to register when the pin comes in contact with the hard rubber section, so that for every revolution of the wheel the register will move one point forward.



CURRENT-METERS.

The register in use is known as the Watch register (Fig. 4).

A stop-watch is inserted in the register and is so arranged that when the watch is started the circuit is closed, and the register announces at once the revolutions the wheel is making, at the same time showing on the watch the exact time to a quarter of a second; and when the watch is stopped the circuit is opened, cutting off the electric current and stopping the register. A third pressure upon the stem of the watch sends the hands back to zero, but still leaves the connection open. By pressing the stem the circuit is again closed and starts the watch for another observation, and so forth. So far, most of the work has

been done with the meter having wheels 7½ inches in diameter, on account of its easy straight line rating equation, of which I will speak later.

Rating.

The most important work to be done to each and every instrument before any good results can be obtained, is to ascertain its rating equation; that is, the number of times the wheel turns for a given speed of the stream must be known. The writer con-

Register.

siders this extremely important, as the accuracy of the work to be done depends entirely upon the care and intelligence exercised in determining the equation for his instrument. Although each instrument is made over the same form, it is impossible to make these so absolutely and mathematically correct that one rating equation would answer for all. The rating is usually done by drawing the meter through quiet water over a course of a given length, and noting the time. By moving the meter slowly or fast through the water over a fixed course we get so many revolutions in a shorter or longer time. The wheel will not record the same number of revolutions when going slow as when going fast; by increasing the speed, the wheel will usually show

an increase of revolutions This is probably due to the friction and inertia of the wheel when going slowly through the water, but as the meter is moved with greater speed the friction is of less importance, and the number of revolutions increases, the ratio of increase not being constant. The meter should not alone be rated before being used, but should be tested, as to accuracy, now and then, as the slightest bend of the flukes of the wheels will change their pitch and consequently the rating. On June 19th

Reduction of Observations for rating Large Haskell Meter with Low Pitch Wheel, made at Mingo Creek. Philadelphia, Pa. June 19th 1896

Number of Revolutions	Time in Seconds	y = velocity feet pr Second	x = revolutions pr Second	xy	x^2	Computed y	v	vv	Diff	Remarks
53	234.50	.626	.226	.0963	.0511	.431	− .005	.000025	.005	Length of Base 100 feet. Meter was placed 4 ft in front of bow of boat and 18 in under surface of water.
63	144.75	.691	.435	.3006	.1892	.686	+ .005	.000025	.006	
64	120.75	.812	.530	.4304	.2809	.802	+ .010	.000100	.029	
68	114.00	.877	.597	.5236	.3564	.883	− .006	.000036	.027	
70	108.00	.917	.648	.5942	.4199	.946	− .029	.000841	.004	
72	94.50	1.058	.762	.8062	.5806	1.085	− .027	.000729	.001	
71	88.50	1.130	.802	.9063	.6432	1.134	− .004	.000016	.002	
73	71.25	1.404	1.025	1.4391	1.0506	1.405	− .001	.000001	.013	
74	56.00	1.786	1.321	2.3593	1.7450	1.766	+ .020	.000400	.031	
74	53.50	1.860	1.383	2.5724	1.9127	1.842	+ .018	.000324	.003	
75	50.50	1.982	1.485	2.9433	2.2052	1.966	+ .016	.000256	.001	
76	46.50	2.150	1.634	3.5131	2.6700	2.148	+ .002	.000004	− .122	
77	33.50	2.985	2.300	6.8655	5.2900	2.960	+ .025	.000625	+ .005	
78	32.00	3.125	2.438	7.6188	5.9438	3.127	− .002	.000004	.010	
78	29.00	3.448	2.690	9.2751	7.2361	3.435	+ .013	.000169	.020	
79	26.00	3.846	3.038	11.6841	9.2294	3.859	− .013	.000169	.018	
79	21.50	4.651	3.674	17.0878	13.4983	4.634	+ .017	.000289	.016	
80	19.75	5.063	4.051	20.5102	16.4106	5.094	− .031	.000961	.002	
80	16.25	6.154	4.923	30.2961	24.2359	6.157	− .003	.000009	.025	
80	16.00	6.250	5.000	31.2500	25.0000	6.251	− .001	.000001	.013	
		50.615	38.962	151.0724	118.9489			.004984	.017	
									.126	
									+ .004	

Number of Observations $n = 20$

$y = ax + b$

$y = 1.219x + 0.156$

$S(x^2)a + S(x)b = S(xy)$

$S(x)a + nb = S(y)$

$118.9489a + 38.962b = 151.0724$

$38.962a + 20b = 50.615$

$a = 1.219$

$b = 0.156$

Probable Error of Results ±.0024

C. Jacobsen, Asst.

TABLE B.

of last year the writer rated in the usual manner the larger size Haskell meter with low-pitch wheel, in the forebay of the pumping station at Mingo Creek. On Table B is shown the rating of this meter.

The difference between the computed and the actual revolutions is extremely small.

The opposite signs are almost equal in number, eleven being minus, and nine plus (to be mathematically correct these should,

of course, be equal in number), and their difference, taking into account the signs, is only .004, and the probable error of results $\pm$ .0025. The equation for this meter is a straight line, $y = ax + b$, where y = velocity in feet per second, x = revolutions per second, and a and b the rating-constants, and these rating-constants should be especially determined for each wheel.

For all practical purposes this rating is correct from about a velocity of 0.2 foot per second to about 7 feet per second. For higher velocities the high-pitch wheel should be used which will register accurately up to 12 feet per second.

From the observations thus made and described above, the rating is determined by two methods, either analytically or graphically. The most correct way is the analytical, as this method is susceptible to greater mathematical accuracy; after the constants have been found then the equation can be plotted on a cross-section paper, be it either a straight line or a curved one, and all subsequent observations can then be readily and quickly read off. The equation for both the low-pitch and high-pitch wheels of the larger meter (each $7\frac{1}{2}$ inches in diameter) shown in Fig. 2, is a simple straight line; while the equation for the small meter (wheels 4 inches in diameter, Fig. 3), is part straight and part a curved line. This last equation is a complicated one. Mr. Haskell rated one instrument, and kindly furnished me with the rating equation. He found that the equations for either wheel was not a straight line for its entire length. For the low-pitch wheel, the equation is:

$$y = 0.3739 + 0.8255x + 0.0846x^2$$

up to the point where $x = 1.86$ revolutions per second, when the equation becomes a straight line, and $y = 1.1402x + 0.0812$, and for the high-pitch wheel, $y = 0.4953 + 1.4201x + 0.1761x^2$ up to the point where $x = 1.86$ revolutions per second, when the equation is:

$$y = 2.0752x + 0.1139.$$

Test of Accuracy.

Having determined the rating equation for each wheel of the larger meter it was thought advisable to check the accuracy of this rating by comparing the results obtained with this meter with those obtained by other well-known methods.

The wheels were first compared with each other and afterwards the instrument was compared with a standard weir.

In Table F are given in figures the rating equations for the larger Haskell meter, for both the low-pitch and high-pitch wheels, and also a table of comparison between the two wheels. The observations were taken in a sewer running at a constant flow and the height of water as nearly constant as could be ascertained by measurement. As soon as the number of revolutions of the high-pitch wheel had been registered for a certain length of time, the meter was quickly drawn out of the water, and the low-pitch wheel put on, and its revolutions registered for the same length of time—in this case 100 seconds. This operation was repeated five times, in order to obtain a fair average of the velocities, as the sewer might not at all times discharge the exact amount of water; as will be noticed, there was a slight variation each time in the velocities, as computed from the equations for these wheels,—still the average of the five observations shows that their rating equations are perfect, the difference or error being only $\pm$ 0.006 of a foot per second. The difference in the velocities as quoted and shown on the table is slight and must be attributed to local conditions. At other points where these equations have been tested the writer has found about the same results; the greatest error being $\pm$ 0.012 of a foot per second, and the smallest $\pm$ 0.001 of a foot per second. This last observation was made in a sewer on Lombard Street, 26 feet deep, where it was especially difficult to handle the meter, wires and connections. Mr. A. J. Fuller, Assistant Engineer of the Water Bureau, and the writer made several experiments in order to compare the discharges obtained from the standard weir at the Wentz-Farm Reservoir, as computed from Francis' formula, the Venturi and Haskell meters. At one time we obtained the following results:

Venturi meter, 353 cubic feet per minute.
Haskell meter, 355.77 cubic feet per minute.

Reduced to gallons per minute the Venturi meter registered 2648 gallons, and the Haskell meter 2668 gallons, a difference of only 20 gallons per minute. At another time the following results were obtained:

By Francis' formula, 25.07 cubic feet per second.
By Haskell vel. meter, 24.94 cubic feet per second.
By Venturi meter, 24.18 cubic feet per second.

Through the kindness of Mr. J. C. Trautwine, Jr., Chief of the Bureau of Water, the writer is also able to present the results of a series of experiments made for the purpose of comparing the results obtained from the Venturi meter with those obtained from the Francis weir-formula. The results of the experiments made at the same time by the writer with the Haskell meter are also presented for comparison. It will be observed that the errors are less than 2 per cent. between this meter and the weir readings.

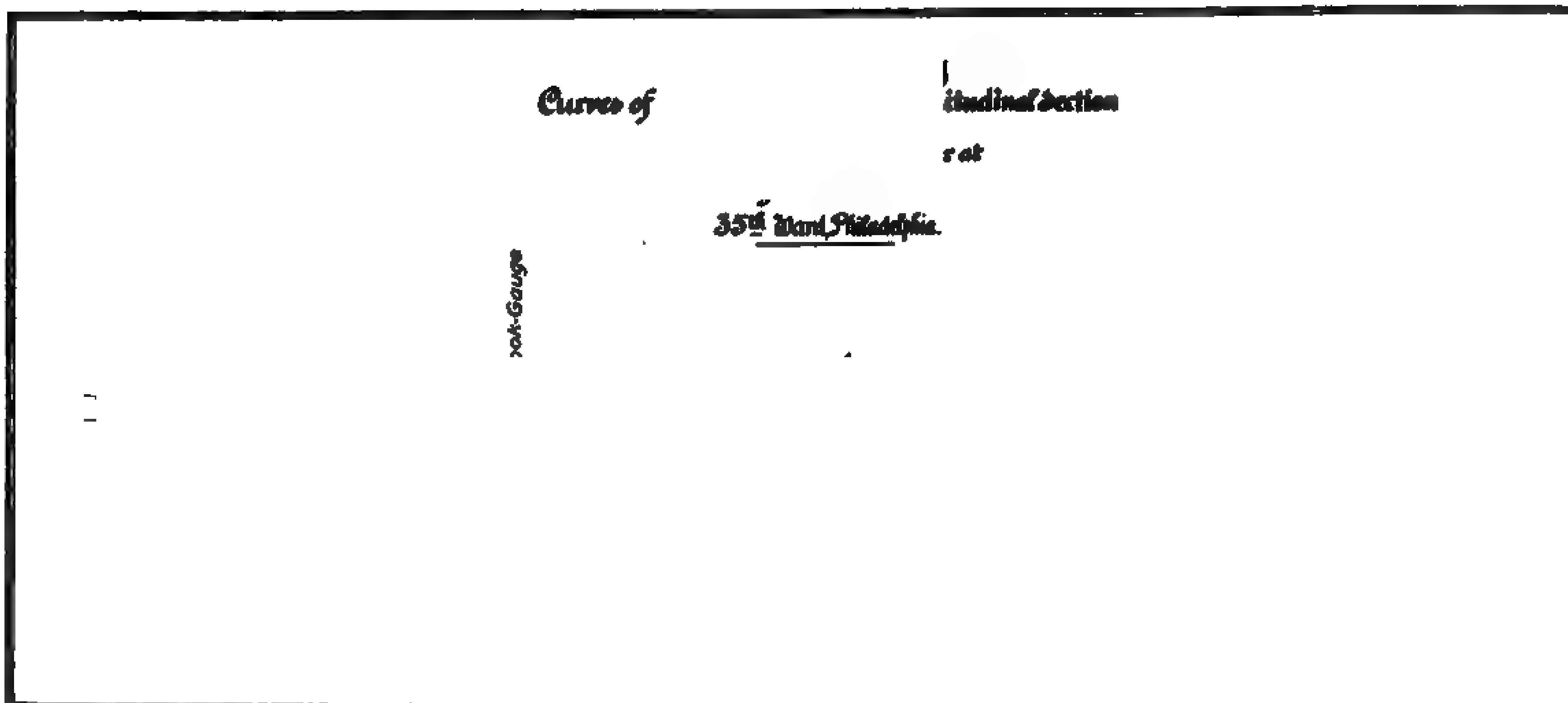
READINGS IN CUBIC FEET PER SECOND.

Weir.	Venturi.				Haskell.	
	Before Adjustment.	Per cent error.	After Adjustment.	Per cent error.		Per cent error.
24.77	24.32	—1.8	24.75	—0.08	24.79	+0.08
29.04	28.83	—0.7	29.19	+0.5	29.22	+0.6
31.93	31.74	—0.6	32.05	+0.4	31.47	—1.5
17.20	16.35	—5.2	16.99	—1.2	16 90	—1.8
21.50	21.01	—2.3	21.51	+0.05	21.49	— 0.05
24.55	24.09	—1.9	24.52	—0.1	24.59	+0.16
28.18	28.03	—0.5	28.41	+0.8	28.33	+0.5
31.98	31.68	—1.0	32.01	+0.1	31.89	+0.3

While making these comparative tests at the Wentz-Farm Reservoir, the peculiar movement of the water in the race leading to the weir was noticed and a series of observations were made to determine the extent and form of this movement, which may, perhaps, be interesting.

The water was pumped into the weir race through a 48-inch water main from the pumping station at Lardner's Point. In order to reduce the velocity of approach to crest as much as possible, a heavy float was placed on the surface of the water near the mouth of the main. The observations which are plotted on Plate G were taken in many places in the race, and these show that the velocity diminishes as the flow approaches the crest; in drawing out the curves of equal velocities, the water seems to

PLATE G.



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have a rotary motion. At the place marked by a cross no velocity could be measured. Where the hook-gauge was placed there seems to be an average velocity. The pumping engine, when these observations were taken, was making 36 revolutions per minute.

The Haskell meter has also been used with excellent results, to ascertain the velocity of the water at different points in the Delaware River at the ends of wharves, and in the docks, with a view to determine the advisability of discharging the sewers at the ends of piers.

SEWER WORK.

As the Bureau of Surveys acquired these meters especially for sewer work, most of the work done has been to ascertain the velocity of the normal flow of water in sewers, but special study has also been made of tidal sewers. The object of the latter has been to determine what influence, if any, the tide would have upon the velocity of the flow in these sewers. During the fall of 1896, the writer was engaged upon this work and took observations at the outlet of the Aramingo Sewer into the canal at Norris Street. This outlet is a twin sewer eight feet in diameter. No difference of flow could be measured in either sewer.

On Plates C, D, E, F, are arranged these observations with regard to the height of tide water in the sewer. These observations were taken under ordinary circumstances, when no storms prevailed and when the normal flow was almost constant. By "No Velocity," as marked on the plates, is meant, that the velocity of the flow is less than 0.18 foot per second, and cannot be measured by the meter.

The line across the circle in the plates indicates the height of the water, and the points indicate the different heights at which the meter was held; the figures to the left of these points denote the elevation from the bottom of the sewer, and the figures to the right the velocity of the water at these points in feet per second; the figures above the circle show the time of observation.

It was especially desired to ascertain if the outgoing or ebb-tide did accelerate the flow of the water in the sewer; but, when a careful study is made of these tables, they clearly demonstrate

ARAMINGO SEWER OUTLET

Nov. 5th 1896.

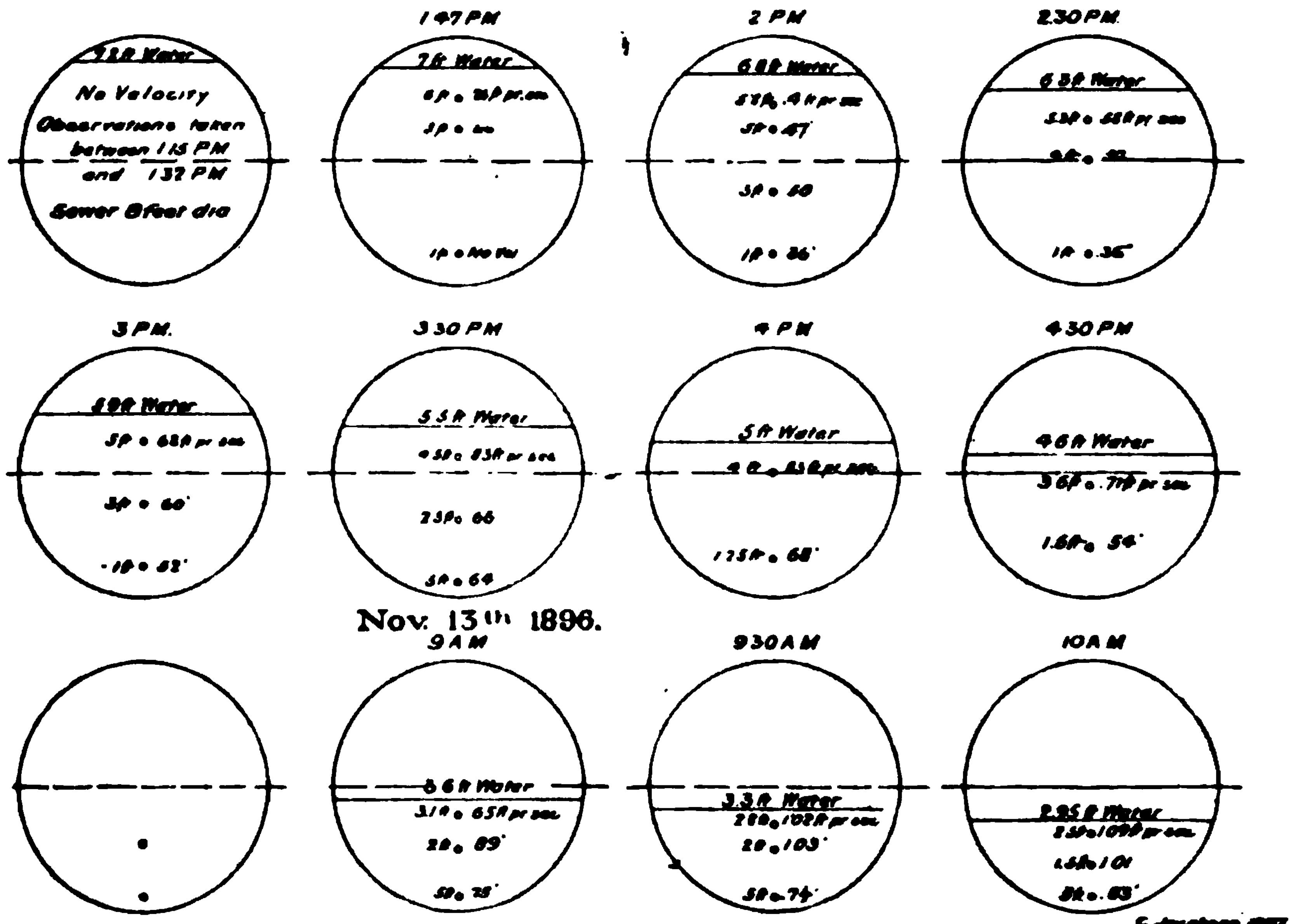


PLATE C.

ARAMINGO SEWER OUTLET

Nov. 6th 1896.

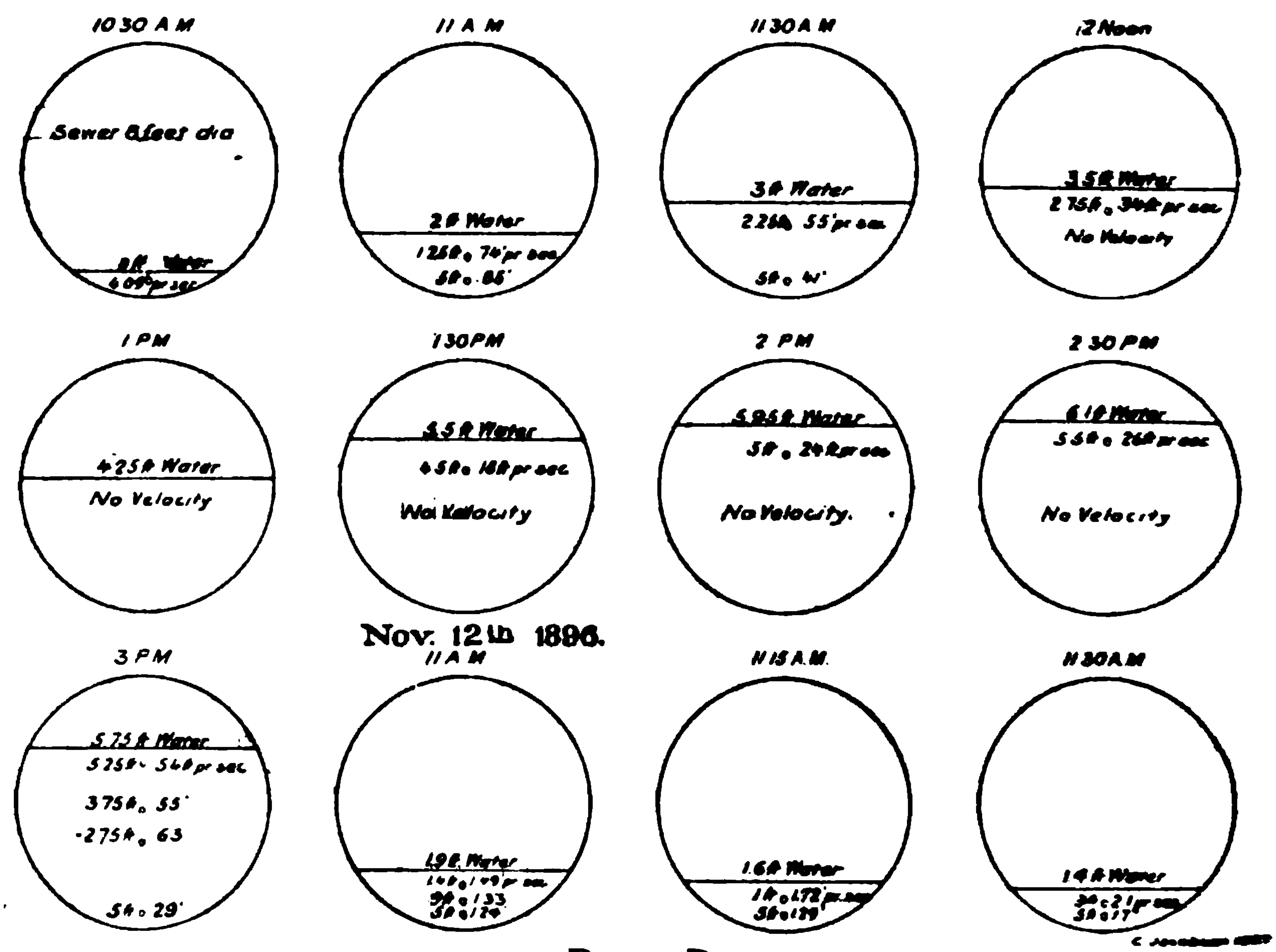


PLATE D.

ARAMINGO SEWER OUTLET
Nov. 13th 1896.

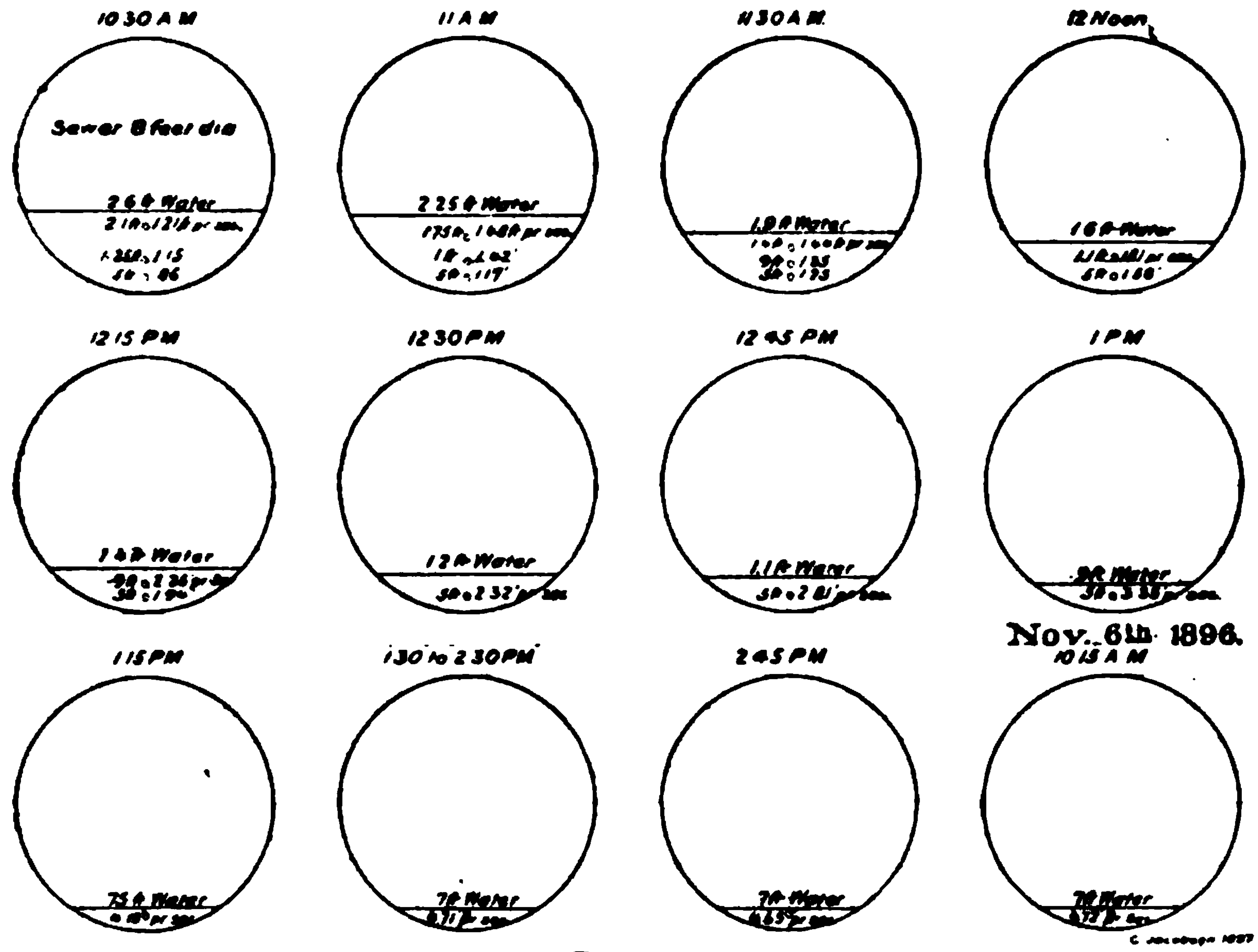
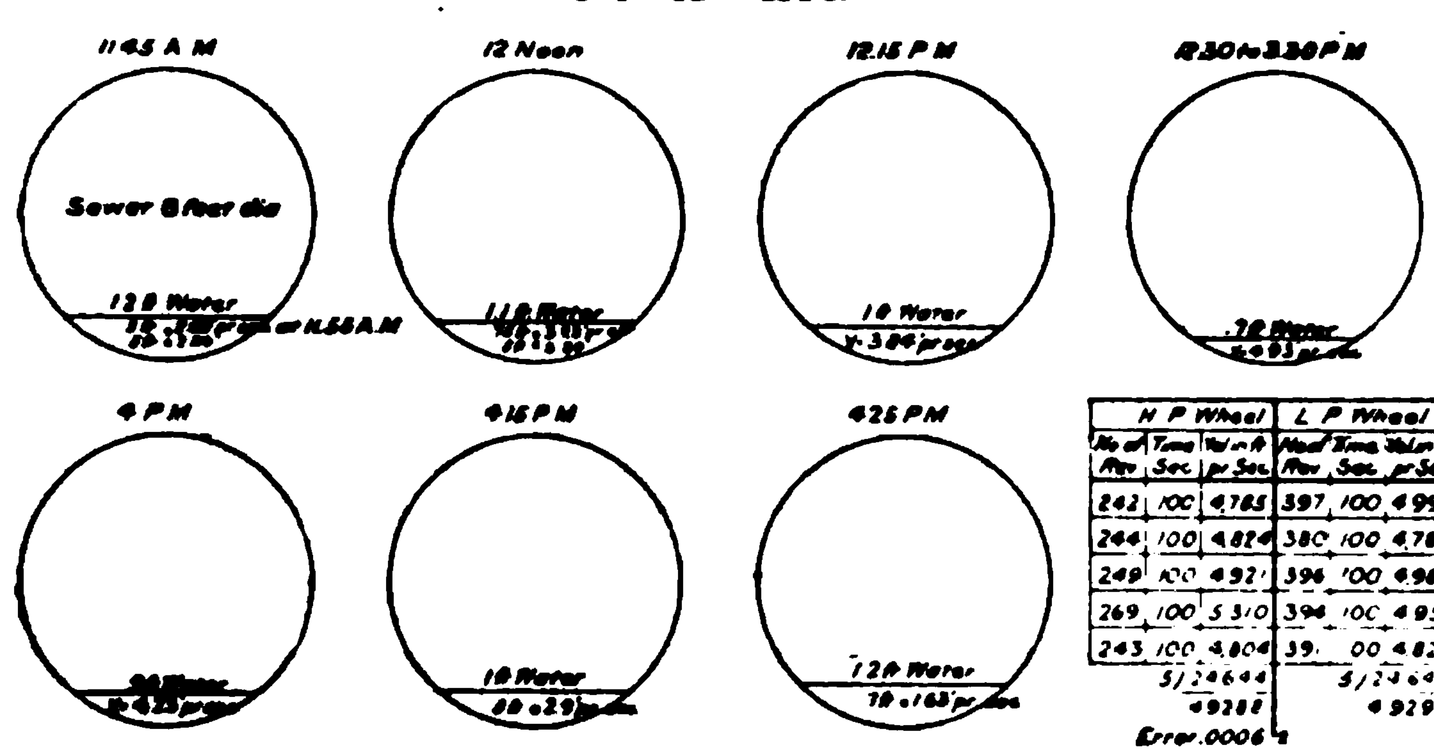


PLATE E.

ARAMINGO SEWER OUTLET
Nov. 12th 1896.



H P Wheel			L P Wheel		
No of Rev	Time Sec	Vel in ft per Sec	No of Rev	Time Sec	Vel in ft per Sec
242	100	4.785	397	100	4.995
244	100	4.824	380	100	4.788
249	100	4.921	396	100	4.983
269	100	5.310	394	100	4.959
243	100	4.804	39[illegible]	[illegible]00	4.822
		5/24644			5/24647
		4.9288			4.9294

Error .0006

Rating Formula for Large Haskell Velocity Meter.

High Pitch Wheel, Vel = 1.945 Rev + 0.078
Low " " , Vel = 1.219 Rev + 0.156

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PLATE F.

that this tide does not help to increase the velocity of the flow, nor tend to help to scour the sewer. The increase in the velocity, as the tide subsided, seemed very gradual, at some points even as on Plate C at 3.30 P.M. and at 4 P.M., although the water, at the last named time, was one-half of a foot lower, the velocities were about the same.

Other facts that these observations demonstrate are, that between the time the tide turned and it commenced to ebb, to the point when the sewer was two-thirds full, the flow reaching a velocity of about 0.5 foot per second, the maximum velocities were found at points midway between surface of the water and the bottom of the sewer.

At any time when the sewer was less than two-thirds full of water the maximum velocity was generally found near the surface of the water. At points nearest to the bottom of sewer the lowest velocities were found. When the flow through the sewer was normal, that is, at low tide, it reached its maximum velocity, or nearly five feet per second. As the flood tide came in, the velocity, as will be seen from the diagrams, was diminished, and was only measurable near the surface of the water; the sewage or normal flow was discharged, although intermittently.

When the flood tide reached the point 4.25 feet above the bottom of the sewer (as at 1 o'clock P.M. on plate D) no velocity could be measured, but when one foot higher or 5.5 feet above the bottom of the sewer was reached at 1.30 o'clock P.M., a small velocity could be observed. From this point until the tide had attained its maximum height there were obtained small intermittent velocities.

The reason for this is as follows: The normal flow did not have power enough to force its way through the tide until it had accumulated enough back-water or head to overcome the resistance of the tide, when it forced its way through. This the writer noticed particularly at 2 P.M. with 5.95 feet of water in the sewer. When first immersed the wheel did not turn; after some seconds it registered a few revolutions, then stopped, and this was repeated, showing that as soon as the head had been utilized, no velocity could be measured until such time when enough back-water had again accumulated to force its passage, and so on.

From the time when the ebb tide set in, the observations show again the small gradual increase in the velocity until low tide was reached, when the maximum velocity was again obtained. The height of the water in the sewer at normal flow was 0.7 foot and the sewer discharged its normal flow above mean low-water. The grade of the sewer is 0.1 foot per 100 feet.

As stated above, the sewage flow was discharged with the tide in the sewer. From observation, and by calculations, it was found that the sewage discharge, at normal flow in this sewer, with no tide water in it, was 10.5 cubic feet per second, when running with 1.08 feet of water, the discharge was 10.9 cubic feet per second, and when 3.7 feet full of water, the discharge was 11.1 cubic feet per second, showing the difference in discharge was very slight. Instead of either tide helping to clean out the sewer, it really does the reverse, as the velocities of the flow are so retarded by the tide as to cause the heavier particles of the sewage to sink to the bottom. At no time, however, between high and low tides, was the observed velocity greater than that obtained during normal flow.

Observations have been taken in sewers at different points of the city, and the velocities of their normal flow obtained.

These experiments illustrate the work that is being done under the direction of the Bureau of Surveys, and when sufficient data have been collected from which positive deductions can be drawn, they will be duly presented in proper form.

DISCUSSION.

Wm. Easby, Jr.—In regard to the discharges of those sewers, what velocity did you use? As I understand, in no case did you make more than three or four observations for velocity. You took several observations in the same vertical, and from these did you observe the discharge?

Mr. Jacobsen.—I took the mean of these velocities.

L. F. Rondinella.—As I understand, Mr. Jacobsen took three sets of observations in each of five cross-sections.

Mr. Jacobsen.—I am speaking of sewers. I took the velocity as I found it in the sewer at those times. Three different times

I figured the discharge in order to see if the sewage did go out while the flood was in. I took the velocity at different points in the sewer. I took it vertically and on each side, and took the average.

Allen J. Fuller.—The data compiled by Mr. Jacobsen show a close approximation to the results obtained from the weir and Venturi meter, and if such approximations can be maintained under varying conditions of flow and cross-section of the stream, it is a remarkably accurate instrument.

In reference to the Venturi meter, I regard it as one of the most accurate instruments for measuring the flow of large streams of water. The register of the meter records very closely with the results obtained with a mercury column, and shows a close approximation with weir measurements. The register of this meter has been found to be invariably accurate for short periods, but it is apt to get out of adjustment when run for any considerable time. This defect is being remedied, however, by using registers driven by weight-power instead of by electricity.

J. Kay Little.—I would like to ask whether Mr. Jacobsen made any observations in sewers not affected by tide.

Mr. Jacobsen.—I have taken some. The sewers I have taken were old sewers, and although they give a little more velocity than by the Kutter formula I do not know if the grade was exact. In building the sewers the grade may have been increased somewhat. I found that in some of the old sewers the grades were slightly increased.

Mr. Little.—You would have to ascertain exactly what the grade was?

Mr. Jacobsen.—The best way to do that is to measure the grade and get the section accurate, and find the velocity.

John C. Trautwine, Jr.—If we had the Haskell or other meter upon which we could absolutely depend, we could make these measurements and deduce the value in any given case.

W. H. Bixby.—In the drawing on the board, showing velocity in nine points at each of five cross-sections, the velocity at the right-hand section some way from the overflow was, if I remember rightly, about one foot per second in the center, a little less above and below, averaging something like $\frac{8}{10}$ foot per

second, while close to the overflow the greatest velocity was only ½ foot per second. At first sight I should think that would show twice as much water moving through the right-hand cross-section as through the left one, which could hardly be correct.

MR. JACOBSEN.—I think it is explained by the buckling motion of the water. While near to the crest it is more steady, the velocity decreases. These movements of the water were just noticed during that time. I noticed it, and Mr. Codman and others with me wanted to find out what that motion was, and we took these measurements in order to see what it was, and those are the results I got with the Haskell meter. It was in drawing out the curves of equal velocity that I got that shape. It was a local acceleration at that point.

JOHN E. CODMAN.—There are several varieties of current meters in the market. The Haskell is the least expensive of any; some cost three times as much. I have had experience with this and the Buff and Berger. They both work on the same principle. The water is like a nut, in which the screw or propeller moves. The rating of it seems to me to be the source of greatest difficulty. Mr. Jacobsen has described the general way of rating them; that is, to place the meter in the still water in front of the boat, and pull the boat along, moving the meter through the water, in front of the boat. In a given length of line, if the water were a solid nut, the meter would make the same number of revolutions, no matter whether it went 100 or 1 foot per second. But as there are inaccuracies in the construction and of friction in the meter, the revolutions are not the same, and there is a certain quantity of what is called slip on the propeller. In Mr. Jacobsen's experiments, the revolutions were from 53 to 80, when, theoretically, they should be the same, whether going at one velocity or another. In rating the meter, the conditions are not the same that they are when it is in use. In one case, the meter is forced through the water, and the power is applied to the meter to turn the wheel; in the other case, the velocity of the water turns the wheel. These two conditions are not alike, although generally considered to be the same. To save the expense of constructing a weir on the Neshaminy, I used the Haskell meter, and compared the observations with those on the weir obtained ten years ago.

The result showed a variation from 1½ to 3 per cent., sometimes more and sometimes less than the weir measurements.

Mr. Jacobsen.—Mr. Codman says he used for his instrument the same rating formula as published, and got results very satisfactorily—1½ to 3 per cent.; but here is one formula, published by Mr. Haskell, and that instrument was tested and did excellent work, and the rating equation for it was, if I remember rightly, this (giving formula on board).

Mr. Little.—In view of Mr. Codman's lucid explanation, I should prefer to use the Cutter formula in preference to the Haskell meter, and I do not think it has any more work about it than the equation resulting from this meter.

Louis Y. Schermerhorn.—It is to be understood that every particular meter has its own equation. I do not know of any discussions of the current-meter more valuable than those made by the Mississippi Commission, and any who wish to study the subject will find that the reports of the Chief Engineers for 1885 to 1890, relating to the survey of the Mississippi River, give very accurate information. The meters there used are the Price meters, the equations giving from 2 to 4 for the first term, while the second term is about 10 per cent. of the first. The methods they adopt for rating the meter are somewhat different, and probably have advantages over others mentioned here.

There the meter has a fixed arm or a fixed radius, traveling around the circumference of a circle about 100 feet in diameter, by means of a weight and a falling pulley. A fixed velocity can thus be had. The meter is placed on the horizontal arm and rotated around this fixed center, describing a path about 300 feet in length, and can be made to pass as many times as desired, so that it may be made to run over 1,000 feet or more by making three or more revolutions. The usual equation accepted is only approximately correct, but it is reasonably so and within such limits as might be accepted as giving a small probable error.

The real facts are, the equation is not that of a straight line, and for low velocities it departs more and more from the straight line near the center of the co-ordinates. The equation of the meter, from zero to the higher velocities, is probably an equilateral hyperbola. In the case presented to-night, the term .156

is supposed to be the lowest velocity in feet per second, under which the meter would barely turn over. In the Mississippi River it is sometimes 0.4, and in other cases .02. I think that the trouble is with the rating of the meter, and as it is used with electrical connections by which the meter registers, you are, of course, subject to all the annoyances an electrical device gives you. On the Mississippi River they now use a flexible tube, prevented from collapsing by a spiral spring, through which the operator listens and counts the number of clicks, and the last reports upon the use of the meter by the Mississippi Commission show that this new device has replaced the electrical device almost entirely.

MAJOR BIXBY.—One reason that I raised a question as to the velocity at the right cross-section, as compared with that of the left section, was to bring out, as I thought it might, the fact that it is essential in using a velocity-meter of this size that the axis of revolution of the meter should be kept parallel with the thread of the current. If not so, there is a liability to great error. In this case, very probably the difference we are referring to is due to the fact, as has already been stated, that the water was in a turbulent condition as it entered from the right, so that the movement of the water was not all parallel with the axis of the wheel, and perhaps some was moving backward. I presume that, in most cases, these meters will be used by the members of the Society in up-river streams, where the motion is tolerably parallel to the axis of the stream; but it is likely some of us may have occasion to use them in tidal water, where it is specially necessary to keep track of the motion of the threads of the water. For example: in Long Island Sound, a good many years ago, many current-meter observations were taken partly for use, and partly for practice. On many occasions, when the water was running tolerably fast towards the east on the surface, it was found that it was also running tolerably fast in other directions below the surface, swinging gradually around until near the bottom, where its direction was almost west; so that, while the water was moving tolerably fast at every point, the total flow in any single cross-section was almost zero.

MR. JACOBSEN.—In large bodies of water, where it is necessary

to determine direction as well as velocity, a combined direction and velocity-meter is usually used. There is one from, by which you can see, from a boat, the direction of the current and at the same time get the velocity.

MR. TRAUTWINE.—I understood Mr. Jacobsen to say that he attempted to measure the velocity immediately over the crest, with considerable difficulty in holding the meter there, and found about 0.56 per second as against 0.81. There, I take it, the particles of water would have been moving in a horizontal direction, and the velocity in so small a cross-section as that must have been very considerably higher.

MR. JACOBSEN.—I did not speak of it, as I did not wish to guarantee its accuracy.

VII.

THE INSTALLATION OF THE NIAGARA FALLS POWER COMPANY.

By Mr. CHAS. F. SCOTT (Non-Member), Pittsburgh, Pa.

Presented, April 17, 1897.

WE pride ourselves upon the great advancement of engineering science, its rapid growth during the present century, and particularly the material and industrial progress of the last few years. If we examine the conditions underlying this development we will find that tools have been a vital factor. If we imagine all tools to be taken away we may realize by their absence what an enormous part they play in our ordinary operations. Take away from the laborer his pick and shovel, from the mechanic his saw and hammer, from the machinist his lathe and planer, and each is helpless. If we, even with our present knowledge and skill, were put empty-handed face to face with nature we could accomplish almost nothing. Take away the knowledge we have and the skill we have attained, let us be without tools and without the knowledge of their value and their use, and we may realize the dark prospect that presented itself to the human race centuries ago. What an enormous problem is presented by the ignorant savage in the primeval forest and what little chance for the evolution of an industrial civilization.

One of the first things learned was the use of simple aids for increasing and directing physical exertion—a club or a bow and arrow. The range of man's activities was greatly increased and he made an enormous stride when he brought brute force to his aid and utilized the greater power and endurance of animals. Greater advance was made when inanimate forms of power were employed—wind, water and steam. Chief of these is steam, which has revolutionized all departments of industry and engineering; its influence upon transportation, where the rumbling stage coach has given place to the express train, is a sample illustration of the extent to which it has modified our methods.

Tools are really a means of applying power. They serve to direct and make more effective muscular power, the power of animals and of steam or wind or water. A history of the development and utilization of power is the history of human progress. The most civilized and most advanced nations are also characterized by the highest development and largest use of power. Engineering in its broadest sense is the science and art of producing, transmitting, transforming and applying power.

The ordinary and familiar sources of power are fuel and falling water. Fuel is energy in potential form, stored in limited amount in nature, while water is energy in kinetic form, which, if it is not used, is lost. The energy of coal is used in a wasteful way, while with falling water a large percentage of the real energy can be utilized. In the broadest sense, therefore, engineering is doing a noble work when it harnesses a dashing river and brings to mankind a new source of power, increasing its quantity and cheapening its cost.

The largest and most notable waterfall in the world is that at Niagara, and it is my purpose to show something of the means which have been taken, within the last few years, for the utilization of this power. It is not my intention to present a formal lecture—rather we will take a trip together about the Falls, to inspect the new electric plants, and I will be your guide, pointing out and explaining some of the features in which you may be interested.

The Falls of Niagara are favorably located. If they were in an uncivilized country there would be no use for the power; if they were in an inacessible mountainous country, where waterfalls are usually found, they might be too far from inhabited regions to be of any value; if they were in a country where civil government was not well established, there would be little protection to large enterprises; but here, under most favoring conditions—geographical, commercial, industrial and civil—this great waterfall lies directly between two of the greatest governments of the earth and in the Empire State of our nation. A glance at a map of the country shows that the Falls lie between New York, the metropolis of the East, and Chicago, the gateway of the West, in direct line of railway and water transportation. New England is famed

stroke and works at a fair rate for eight hours per day it would take about ten times the total population of the United States to pump the water back as fast as it is flowing over the Falls. Consider for a moment what this means. If 70,000,000 of us were engaged in manual labor all the work we would do could be accomplished ten times over by the power which is now going to waste. All the work of laborers, all our actual exertions in digging, hammering, lifting, climbing stairs, running sewing

THE EXTENSION OF THE WHEEL PIT.
Loaned by *American Electrician.*

machines or riding bicycles probably do not represent the one-hundredth part of this stupendous power. This shows the great field of possibility open to engineering and illustrates how feeble are our powers compared with the forces of nature about us, and how enormously our activity may be increased by bringing other sources of power to our aid. The cost of the production of materials in manufacturing concerns and building construction of all kinds consists largely in the cost of power. Here at Niagara

is unused power equal to that of all the coal mined in the world. The great and difficult problem is how to apply this power.

If we stand on the suspension bridge just below the Falls we may see an incline from Prospect Park to the foot of the gorge. A car is at the bottom, filled with passengers, and a large tank at the top, which is filled with water. The car and the tank are connected by a cable which runs around a large pulley. The weight of the water in the tank exceeds that of the passenger car—the car ascends, the tank descends and the water is discharged. This is one of the simplest applications of Niagara power. Looking from the suspension bridge down the river on the American side we may observe a score of streams of water issuing from the side of the cliff at various elevations—mostly near the top. This is the discharge from water wheels which supply power to the various mills and factories along the top of the cliff. A large proportion of the power is wasted, as only a small part of the available head is utilized. At the bottom of the cliff near these many little waterfalls is a new building, in which a much higher efficiency is secured. The water descends through a great penstock 9 feet in diameter, and practically the full head of the water is effective at the turbines. About 6500 horse-power is used for driving dynamos which supply current for manufacturing aluminum at the head of the cliff and for operating a street railway. The Niagara Falls Hydraulic and Manufacturing Company bring the water for this service from the river about a mile above the Falls through a canal to the head of the cliff about a quarter of a mile below the Falls.

Not far from this power house at the edge of the river and nearly under the end of the suspension bridge is an opening which looks like the mouth of a great sewer and which sends out a current which can be observed half-way across the river. It is the terminal of the tail race, the end of the tunnel of the Niagara Falls Power Company's great plant.

When the problem of utilizing power on a large scale was taken up a few years ago, various engineering plans were considered. Certain necessary conditions were imposed. The river near the Falls must not be disturbed nor its natural scenery marred. The water must be taken from the river at some distance above the

MAP AND PROFILE SHOWING LOCATION OF TUNNEL.

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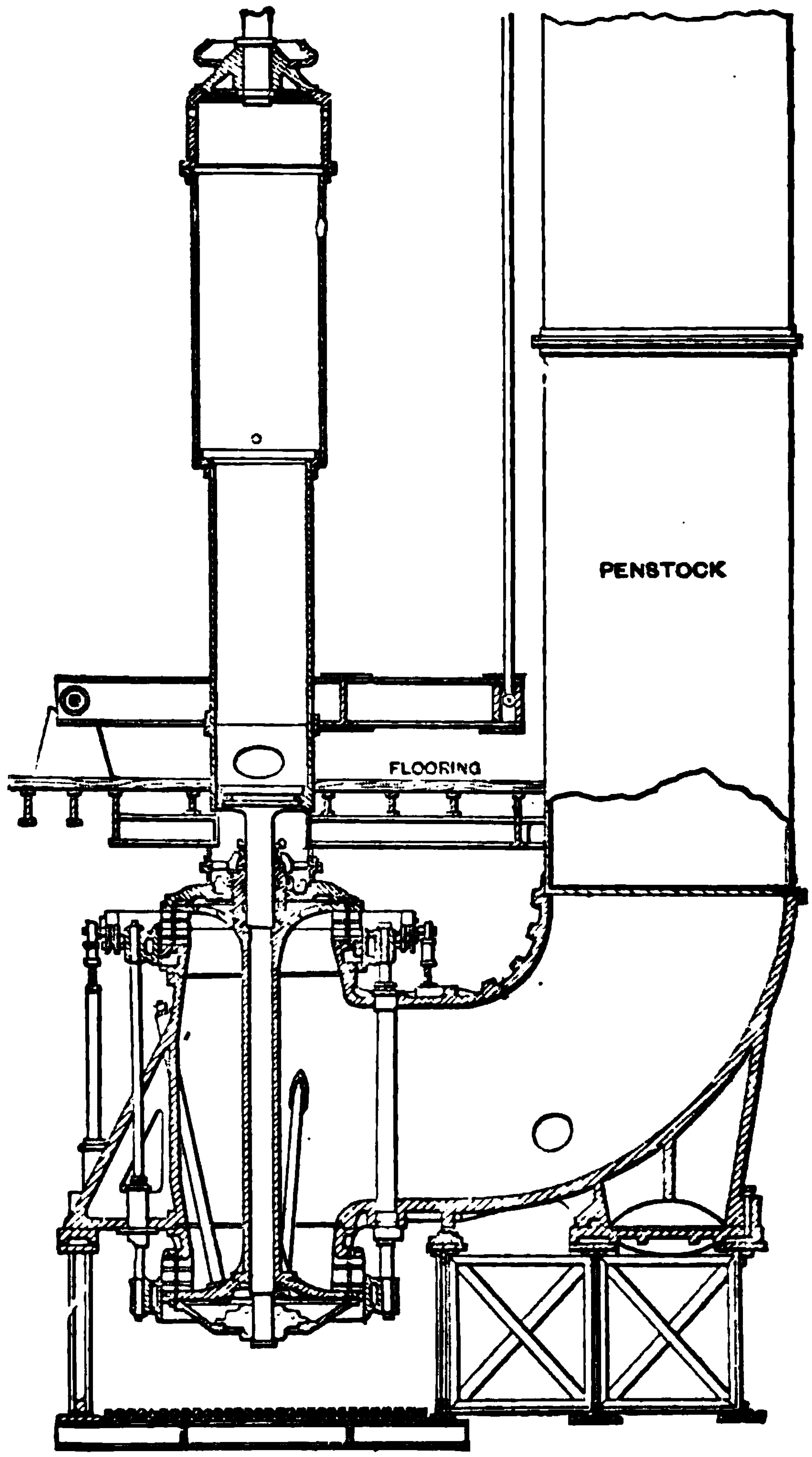
Falls and of course discharged at some point below the Falls. If carried over the surface the right of way through the village would be difficult to secure, and the canal, which would be a mile or more in length, must have a large cross-section or a very considerable inclination, involving a great depth at its lower end—either of which would require extensive excavation. There is not the facility for placing manufacturing establishments and power plants at the bottom or along the cliff below the Falls that there is near the point at which the water must be taken from the river. Even if it were practicable to construct works at the foot of the cliff the cost of excavation and construction would be excessive. After full consideration the plan was adopted of letting the water descend near the point at which it is taken from the river and then discharging it through a tunnel having the shortest route to the river below. The tunnel has a grade of 6 feet per thousand or a total fall of about 40 feet.

Large consumers of power, such as the Niagara Falls Paper Company, draw their water directly from the river and discharge it into the tunnel. Ordinarily it is the supply of water which is limited and there is unlimited capacity for the waste water. In this plant the conditions are reversed, the supply is unlimited and it is the tail-race capacity which must be purchased of the power company by individual consumers.

The large bulk of the power is not directly utilized but is transformed into electric energy in the power plant of the Niagara Falls Power Company. The water for this purpose is received from the river about a mile above the Falls through a canal having a width of 250 feet at the mouth, an average depth of 12 feet and a capacity of 120,000 horse-power. The water passes along the canal for about 200 yards and then through inlets into penstocks, which carry the water nearly to the bottom of the wheel pit. The wheel pit is excavated out of the solid rock; it has a width of 20 feet and a depth of 178 feet. Each penstock supplies a turbine having a normal capacity of 5500 horse-power and a speed of 250 revolutions. The turbines were designed by Faesch & Piccard and were built by the I. P. Morris Co. of Philadelphia. The water enters the turbine at one side and is discharged radially both at the top and at the bottom. The shaft is vertical.

The water is given a tangential direction by a large number of fixed guides which are just within the moving buckets. The flow of water is regulated by two external rings, one at the top



SECTION THROUGH A TURBINE.
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and the other at the bottom of the turbine, which may be raised or lowered, permitting free egress of the water or reducing the opening, as may be required. The turbine is so arranged that

the shaft and the weight upon it are borne upward by the pressure of the water. This pressure is reduced as the rate of flow becomes

A TURBINE GENERATOR.
(Copyrighted by *Cassier's Magazine.*)

greater. The weight is exactly balanced at about two-thirds load. The water from the wheel discharges into the bottom of the wheel pit and flows through the tunnel. The tunnel is about 21 feet

high and 19 feet in width and has a cross-section of 386 feet. The velocity of the water in the penstock when it reaches a fully loaded turbine is about 70 miles per hour, and in the tunnel it is about 20 miles per hour. The construction of the wheel pit and the tunnel were engineering works of large proportion. The work of one thousand men for three years was required in the tunnel; 600,000 tons of material were moved and 16,000,000 bricks and 60,000 cubic yards of stone were employed in the construction. The tunnel is lined with brick and at its portal is constructed of granite and steel and has an increased pitch.

We have followed the water in its course from the river to the river again, driving the turbines as it passes. We will now trace the mechanical energy from the turbines. The location of the dynamos to be driven by the turbines, was a unique problem; they could not well be placed close to the turbines as the additional excavation necessary for placing the machines 140 feet below the surface would involve considerable cost, and as the dampness, almost inevitable in such a place, is not at all inviting for electrical apparatus. The plan adopted was to mount the dynamos at the top of the wheel-pit and drive them by vertical shafts extending upward from the turbines. One of the difficult elements in a water-power plant is the regulation of speed, especially when electrical apparatus is to be employed, where close regulation is necessary and where sudden fluctuations of load are liable. As the supply of power to a wheel of such large size and under such great head cannot be instantly changed, it is essential to have a fly-wheel of large capacity. If this fly-wheel be located at a distance from the dynamo then a sudden change of load will bring severe stress upon the shaft. In this plant the fly-wheel has been incorporated as a part of the dynamo by making the heavy external part of the dynamo revolve. A governor, of Swiss design, is placed on the floor of the station near the generator whose speed it regulates. It has as its controlling element a fly-ball governor at the top. This is connected through an apparently intricate mechanism for securing delicacy and precision to the elements below. In the lower part of the governor there are two belts which are driven from the main shaft by gearing below the floor. The action is such that when the power

VERTICAL SECTION THROUGH POWER HOUSE AND WHEEL PIT.
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is to be increased or diminished the motion from one or the other of these belts, which are running in opposite directions, is communicated to the vertical rod which adjusts the position of the rings which control the escape of water from the turbine. The governor acts quickly and for all ordinary changes in load gives a practically constant speed.

The long and already heavy shaft carries an additional weight of the revolving part of the dynamo of some forty tons. The problem of mechanically supporting a shaft nearly 140 feet long, of such an enormous weight, was one of the peculiar difficulties in the design of this plant. A thrust bearing was adopted having a number of circular rings resting in grooves in the fixed bearing, lubricated by circulating oil and cooled by running water. The balancing effect of the upward pressure of the water in the turbine is such that the pressure on the thrust bearing is usually small. The shaft is a seamless steel tube 38 inches in diameter, which is reduced to 11 inches in section at certain points where guide bearings are placed to prevent deflection.

The shaft extends upward through the center of the dynamo and carries a steel driver very similar in form to an umbrella. The circumference of this top or driver carries a great steel ring nearly 12 feet in diameter, 5 feet in height and 5 inches in thickness. On the interior of this ring are bolted 12 steel poles which are surrounded by coils. This part of the dynamo is the field. It is similar to ordinary dynamos in having an outer yoke or rim which supports inwardly projecting poles and differs from them in being horizontal instead of vertical, and revolving instead of being stationary. Inside of the field is the armature, which consists of a hollow cast-iron support on the outside of which are placed horizontal sheets of laminated iron, forming a great ring just within the field poles. The laminated iron has a large number of vertical slots, through which the copper bars which constitute the armature windings are placed. This machine is especially noteworthy as it is the only electrical apparatus of 5000 horsepower that has been built, and as it involves new features in construction. The new design was exacting, as both mechanical and electrical requirements were involved. For instance, the field-ring must embody great mechanical strength and high magnetic

permeability. To meet the former nickel-steel was demanded, and it was a fortunate coincidence that while a large percentage of nickel utterly destroys the magnetic permeability yet the small percentage which gave the proper mechanical characteristics improved the magnetic qualities. The ring was forged from a great ingot by the Bethlehem Iron Works. The greatest skill in designing, construction, testing and erection was required to secure a balancing of parts so perfect that no vibration of the capstone on which the armature rests can be noticed. This dynamo with its great power and its high speed renders the output per weight exceptionally high, so that even a small loss of energy in the machine causes a comparatively large loss per pound of material. This requires special means for removing the heat and avoiding undue increase in temperature. Special provision has been made for ventilation, and around the bearing within the dynamo there is a water jacket for removing the heat. This method has been extended to the armature and a flow of water passes through certain spaces within the armature for conducting away the waste heat. In a small space less than 12 feet in diameter and 5 feet in height, a large part of which is vacant or is used for ventilation, we have the conversion of 5000 horse-power from mechanical into electrical energy.

When the dynamo is running and an ordinary direct current flows through the coils around the poles on the revolving field, alternating currents are induced in the stationary windings in the interior armature. Ordinary commercial currents are of two kinds, direct and alternating. The direct current is one which flows constantly in one direction. It has a mechanical analogue in the continuous flow of water through a pipe or in the transmission of power by a belt. An alternating current corresponds to a reciprocating motion. If a pipe have a piston in one end which is drawn back and forth so that the water within the pipe has a reciprocating flow, the action is somewhat analogous to that of the alternating current. Corresponding to the comparison between direct current and a belt we may liken alternating current to motion by a crank. As there are varieties of cranks there are varieties of alternating currents. A shaft may be driven by a single crank or by two or three cranks intermittently. In

the same way an alternating current system may employ more than one current, the several currents acting successively. As the uniformity of motion in a shaft driven by an engine of several cranks is greater than when a single crank is used, so the flow of energy or supply of power, which must be intermittent when a single current is used, may be made uniform and constant from two or more suitably adjusted currents. The winding on the Niagara generators is such as to produce two alternating currents, each of which has its maximum value when the other has its zero value. These two currents are conducted by four wires to the switchboard. Any of the dynamos may have its four wires connected to either of two sets of bus-bars. Switches connect the outgoing circuits to one or the other of these sets of bars. Suitable instruments are provided in stands on the switchboard platform for indicating the pressure or electro-motive force and the current, also the power which is delivered by each circuit of each machine.

The frequency in this plant is 25 cycles, that is, the complete cycle of the current occurs 25 times per second, or, expressed in another way, there are 3000 alternations or reversals of the current per minute. This is considerably less than is used in ordinary electric plants where the frequency in this country is either about 7200 or 16,000 alternations per minute. The low frequency was adopted because it is more suitable for power work, for transformation into direct current, and for long-distance transmission. The pressure or electro-motive force delivered by the dynamo is 2200 volts. This pressure is suitable for supplying power in the immediate vicinity, but is not suited for transmission to a distance. For this purpose high pressures are required in order that the volume of current may be reduced and the requisite size of conducting wires diminished. A two-phase system is best suited for the local distribution, as it possesses certain advantages in regulation of pressure and adaptation to the service to be supplied. On the other hand, three-phase current, or a system in which there are three currents following one another at equal intervals of time, has advantages for long-distance transmission, as the number of wires and the weight of copper required are reduced. The transformation from a low-tension

two-phase system to a high-tension three-phase system may be illustrated by mechanical analogue. Suppose a shaft driven by a two-cylinder engine in which the cranks are set at right angles and have but a short stroke and require therefore strong and heavy connecting rods. On this same shaft let there be three equally displaced cranks which are long and consequently give a high velocity to the rods to which they are connected. The rods which are moving at the higher velocity may be comparatively small and light and may therefore be carried to a considerable distance without exceeding moderate dimensions. By a similar arrangement at the other end of the rods the motion may again be reduced by letting the three rods be connected to three cranks on a shaft which is provided with two short cranks driving rods at slow speed. In the electric system heavy wires or copper bars conduct the two-phase current from the generator to raising transformers, which supply a high pressure to an outgoing circuit and which are connected in pairs in such a way as to deliver a three-phase current to the three outgoing wires of the transmission circuit. A reversed arrangement may be used for re-transforming to two-phase currents at low pressure.

Three generators are at present installed, and contracts have been let and work is progressing rapidly for the installation of five more. Each group of five machines has a switchboard for regulating and controlling the current and supplying it to the outgoing circuits. The raising transformers are located in the transformer house on the opposite side of the canal from the power house and connected with it by a stone bridge.

We have now taken a general view of the plant, following the water from the river through the penstocks, the turbines and the tunnel to its discharge into the gorge. We have followed the power developed in the turbine up the shaft and through its conversion into electrical energy in the dynamo and have seen briefly the general character of the currents produced and the methods of handling and transforming these currents in the power house. We will now follow the circuits from the power house and find the destination of this power.

Before taking up the commercial application of the Niagara power it is interesting to note the immediate uses of water power

and electric power in the power house itself. The switchboard attendant throws his switches by air pressure which is obtained

Transformer and Regulator.

Section of Furnace.

PLANT OF THE CARBORUNDUM COMPANY.

Loaned by *American Electrician.*

from water power. The pumps for circulating oil are also driven by water power. The power house is heated and lighted electric-

ally. The intake gates along the canal are operated by motors. The elevators and the cranes, the alarm system, and even the clock, depend upon electricity, and the connections between the armature bars were soldered electrically.

The first commercial use of the electric power was by the Pittsburgh Reduction Company in its extensive works on the river a short distance above the power house, for the manufacture of aluminum. The current is reduced in pressure from 2200 volts to a low voltage and is supplied to machines for transforming the alternating current into direct current. These machines perform the double function of operating as alternating-current motors and as direct-current generators. The machines are similar in general to direct current dynamos, with the addition, however, of collector rings for receiving the alternating current and introducing it at suitable points in the armature winding. A mechanical analogue is found in the shaft of an engine which receives power by two cranks from reciprocating rods and delivers it to a belt running in a constant direction. This plant has a capacity of nearly 4000 horse-power, which is used in the form of direct current at about 160 volts for the manufacture of aluminum by the Hall process.

In the works of the Carborundum Company a large transformer and a regulator are installed which deliver 1000 horse-power of alternating current to electric furnaces for making carborundum, the new abrasive, whose hardness is exceeded only by that of the diamond. The suitable materials, salt, glass-sand, saw-dust and coke, for making the carborundum are placed in a furnace built of loose bricks and the current is passed through from one end to the other. The passage of the current produces heat throughout the interior and raises the temperature to a very high degree. The resistance changes during the process, requiring an adjustment of the current in order to maintain a constant supply of energy. This necessitates a change in pressure from about 250 to 100 volts. After about twenty-four hours a compound of silicon and carbon is formed, the amorphous central core being surrounded by beautiful crystals.

The Acetylene Light, Heat and Power Company manufactures calcium carbid by the union of lime and coke in the pres-

ence of an intense heat generated by the electric arc. The current passes between two enormous terminals or electrodes which

Furnace at Work.

Furnace Dismantled.

PLANT OF THE CARBORUNDUM COMPANY.

Loaned by *American Electrician.*

are separated by several inches and the arc through this space radiates an intense heat. The powdered materials surround this

arc. The arc gives an intense light and a loud humming sound having a frequency corresponding to that of the alternations of current. This company has operated with a 1000 horse-power transformer which reduces the pressure to 100 volts. It is now installing several more transformers of the same size.

The Niagara Electro-Chemical Company uses about 500 horse-power in direct current for the manufacture of metallic sodium by the Castner process. The current is delivered at a voltage which may be varied from 125 to 165 volts by means of a regulator connected with the lowering transformers. The number of turns in one of the windings of these transformers may be varied at will, thus changing the ratio between the number of turns in the two windings and thereby raising or lowering the resulting pressure, which in turn varies the pressure delivered by the machine which supplies direct current. One of these machines is the first of its type. It differs from other machines in having no field coils and is termed an "induction rotary." The magnetizing effect, which is usually secured by direct current through the field winding, is here obtained from the alternating current through the armature winding. It possesses many elements of excellence in simplicity of construction and operation.

The Matheison Alkali Company is now installing a plant in which about 1500 horse-power will be used in the form of direct current at a voltage variable from about 175 to 225 volts.

The electric light plant for the village of Niagara Falls has in addition to its former steam plant two 400 horse-power induction motors which receive power from the Niagara generators and are used for driving the dynamos which supply the commercial lighting circuits. Much of this lighting might be supplied directly by the circuits from the large generators, but a part, notably the arc lighting, cannot be thus supplied and the motors were introduced as a simple mechanical arrangement for furnishing power to the existing plant. The induction motor possesses many advantages over its rival, the direct-current motor, not only as regards electrical performance, but especially in its mechanical characteristics. As is well known, the commutator in direct-current machinery is the element which is most difficult to construct and which is the part most liable to accident and

Induction Rotary. Rotary with Field Coil.

NIAGARA ELECTRO-CHEMICAL CO.—ROTARIES FOR TRANSFORMING ALTERNATING INTO DIRECT CURRENT.

Loaned by *American Electrician.*

deterioration and wear, and which calls for care and skill in attendance. This feature is entirely absent from the induction motor, which in its most approved type has no open nor moving electric contacts whatever. The revolving element is ideally simple. It consists of an iron core with holes near the circumference, through which are placed copper rods which are securely bolted to rings at each end. The currents in this element are induced through magnetic action from the currents in the coils on the outer stationary part of the machine which are received from the supply circuit. The induction motor tends to run at a certain definite speed and falls off a trifling amount from this speed as it is loaded. The synchronous alternating current motor must run at a perfectly definite speed, and when the speed falls below this amount caused by overload or otherwise the motor will stop. It is much more sensitive in its operation and requires closer adjustment and attention both mechanically and electrically than the much more flexible induction motor.

Mechanical power is supplied from Niagara circuits for various minor operations, such as driving fans, pumps, crushers, etc., in connection with the various establishments which have already been described.

The only present use of mechanical power on a large scale is in the operation of street railways. Direct current at a pressure of about 500 volts is obtained for this purpose through the agency of transformers for reducing the pressure of the main circuits and rotaries, which are similar to the machines at the various chemical works which receive alternating and deliver direct current. Three machines of 500 horse-power each, are located in one end of the power house and supply current to the railways in Niagara Falls and to the Niagara end of the road to Buffalo.

We now have completed our examination of the diversified methods of using electric power near the generating plant. The feature, however, which attracts the greatest popular interest is the transmission to Buffalo. In the transformer house are two transformers, with a total capacity of 2500 horse-power, which transform the 2200 volt two-phase current into 11,000 volt three-phase current which is carried by three heavy copper cables on a substantial pole line to the outskirts of Buffalo, where it passes

into cables in an underground conduit to the power station of the city railway plant, a total distance of twenty-seven miles. Here the current is reduced in pressure, is transformed into direct current and supplies about 1000 horse-power to the trolley circuits.

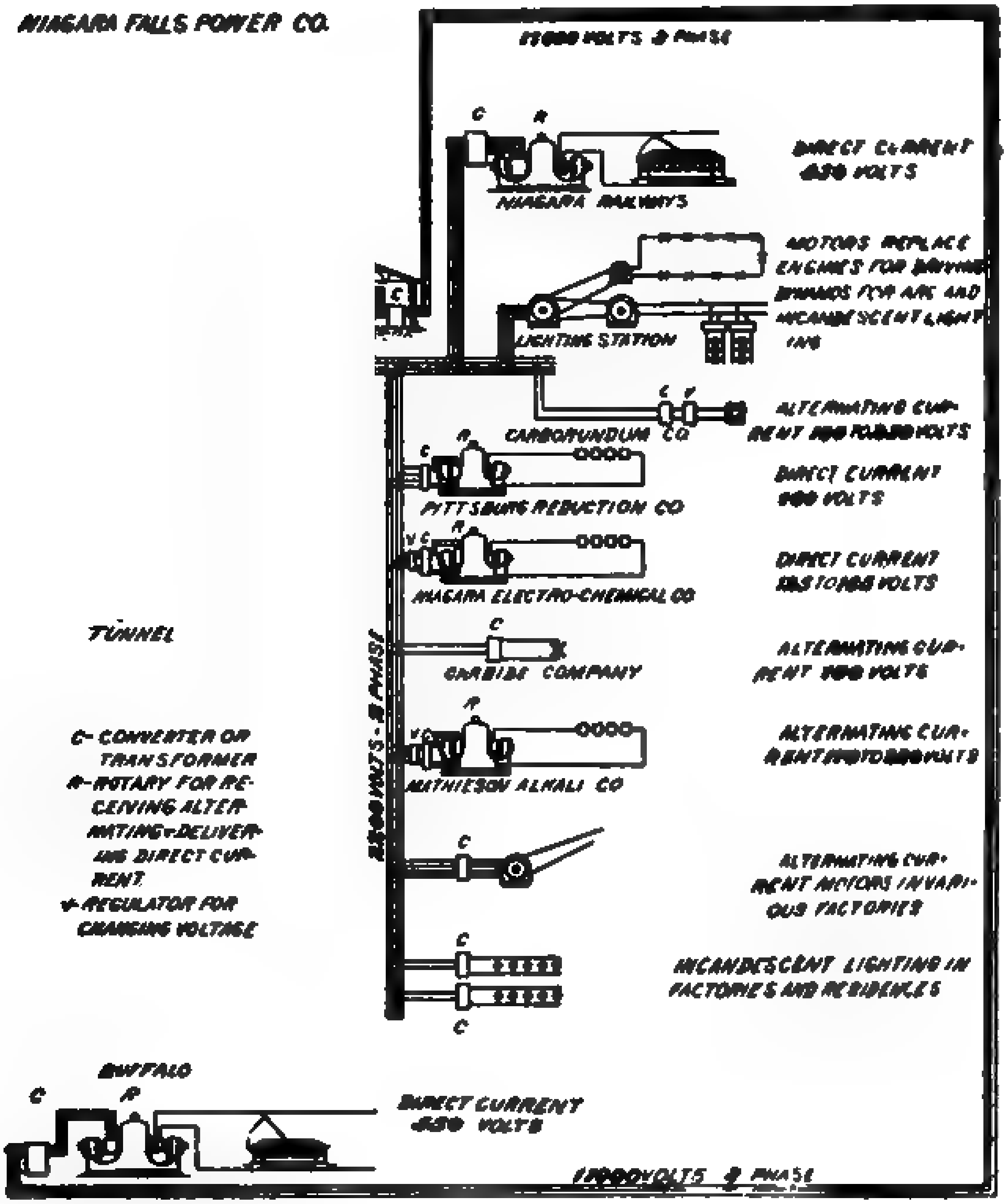


DIAGRAM OF CIRCUITS.

It is proposed to increase the transmission voltage to 22 000 volts and supply power on a large scale for general purposes as soon as the apparatus can be installed.

This cursory examination of what is being accomplished within two years of commercial operation impresses us with the magnitude of the engineering projects, the versatility and flexibility of the electric system and the newness of the industries which are operating. It is of special interest to note that the great field ring, the dynamos and the turbines were all constructed in the State of Pennsylvania, and that no engineer has had more to do with the enterprise, from the time he was acting as the only American member of the International Commission which considered the preliminary plans until its completion under his intelligent and painstaking direction, than your honored fellow-member, Dr. Coleman Sellers.

The current from Niagara generators is supplying almost every kind of electrical industry. It is transformed into direct current at constant voltage and at variable voltage. It is transformed as alternating current to a low voltage, either constant or variable, and to a high voltage, for transmission. The current is used for developing mechanical power which replaces steam engines, does miscellaneous work and operates street railways. The current is used for lighting and for ordinary heating. In the new processes the current is used for its electrolytic and heating effects. Heating is produced, both by direct passage of the current through materials sometimes in liquid form, sometimes in solid form, and by the electric arc.

The important enterprises at Niagara are new. The processes are among those which electricity has so recently given to the arts. They are large consumers of power and their commercial practicability depends upon its cheapness. In ordinary manufacturing industries the cost of power is a small percentage of the cost of material and labor, and the power is used only a small part of the day. In the industries at Niagara the cost of power is the vital element, and while on the one hand their continuous operation makes them ideal customers of a water-power plant, on the other hand they are significant omens of the advance in the industrial methods which is made possible by abundant and cheap power.

DISCUSSION.

COLEMAN SELLERS.—It has afforded me much pleasure to follow Mr. Scott's description of the work of developing the power of Niagara Falls, particularly his statement of the electrical conditions and explanation of the mode of meeting the requirements of the problem.

He has called attention, I notice, to an important improvement in the transmission of electricity. From two-phase generators which need four cables for such transmission he has explained, how, by conversion into three phases in the step-up transformers three cables only are required to form the line, thus saving 25 per cent. in copper and the same amount in the number of insulators needed. He modestly refrained from connecting his own name with this important invention, which he made public at a meeting in Washington, D.C., when the study of the subject for the Cataract Construction Company was exciting the inventive faculty of competing electrical manufacturing companies.

Mr. Scott's use of the two throw cranks analogue in explaining the advantage of two-phase generation has been enhanced by his ingenious comparison of the principle of the step-up transformer to short radius cranks with heavy connecting rods receiving the power from the prime motion, while long radius cranks and lighter connecting rods for the transmission of the power to a distance is new to me and must be hereafter associated in my mind with others of his happy thoughts.

In following the rapid progress in the art of generating and transmitting electricity I have had repeated conferences with the technical staff of the leading companies engaged in manufacturing electrical appliances, and as I am familiar with what they have done to advance the art, I can fully appreciate Mr. Scott's contribution to this advancement by economical methods, and recognize his part in the inventions he has briefly mentioned this evening.

In regard to the fact that the turbines at Niagara Falls were designed by foreign engineers, it may interest you to know something of the circumstances that led thereto. Certain fixed con-

ditions and requirements were submitted to turbine builders both in this country and in Europe. At the recommendation of the Niagara Commission that met in London in 1890, a unit of 5000 horse-power had been adopted under the available head of 136 to 140 feet, and prescribed speed 250 r. p. m. No turbine of 5000 horse-power had been built by any manufacturer, and none of the commercial sizes of turbines on the market could be utilized. A new design was therefore required to meet the conditions and many plans were submitted. The design of Messrs. Faesch & Piccard, of Switzerland, proved to be the most acceptable and was accordingly adopted. This firm had previously designed no turbines of over 700 horse-power and the nature of the problem as presented required much study and could be met only by wide departure from common practice.

While designed abroad, the turbines and machinery connected therewith were built in this city, and so far as the operation of the wheels themselves is concerned, we have every reason to be satisfied with our choice. Some radical changes had to be made in the few bearings needed to steady the revolving shaft, for while designed in accordance with the best European practice they did not meet the conditions, and were therefore modified on lines well established by long experience in America, but not familiar to all engineers. More than thirty years' experience in manufacturing shafting enabled me to design the bearing that has been so successful in the present case. The construction of the turbines was well under way before any conclusion had been reached as to the character of the electrical system to be employed. The dynamos were not ordered until 1893, and at that time little was known as to what uses the power developed would be applied. Mr. Scott has explained to you that the system adopted was considered by experts as best adapted to power purposes. This differs in many ways from what, to a limited extent, was then in use in operating machinery by direct-current motors. He has explained by diagram the perfect elasticity of the multiphase alternate current system, and the great scope of its economical utilization. With this in mind, you can well appreciate the value of the selection, considering the paucity of data at command to aid in designing the power-house, and in anticipating the character of the appliances to be accommodated therein.

At the present time the wheel-pit and power-house at Niagara Falls are being extended, and new machinery is well under way. Five units, each of 5000 horse-power, will be added to the three now in operation. The extension of the machinery is in harmony with the present plant, which was considered experimental by most engineers. A careful study of the operation of the turbines and of the dynamos has enabled improvements to be made in the direction of simplicity and increased durability. The efficiency promised by the makers of the existing plant was deemed by many engineers as problematical. For the new machinery a higher efficiency is guaranteed and I have confidence in the result. The new dynamos will not differ in outward appearance from those in use, the changes being mainly in the armature for the diminution of copper and iron losses and more perfect ventilation.

The present dynamos are excited from steam-driven D. C. generators, or can be self-excited from rotary transformers. In the extended plant the excitation will be from direct-current dynamos, driven by special turbines of American design, arranged in a group in the middle of the long line of dynamos, which thereafter will be operated wholly by water-power. The anomaly of so large a water-power being dependent on steam for its ability to generate electricity will thereafter cease to obtain in practice, as sufficient direct current will be generated from turbines to excite the fields of ten dynamos and also operate such D. C. motors as are required in the house and to supply all arc lights used on the premises.

VIII.

SUPERSTRUCTURE OF THE DELAWARE-RIVER BRIDGE AT BRIDESBURG, PHILADELPHIA, FOR PENNSYLVANIA AND NEW JERSEY R.R. CO.

By Paul L. Wolfel, M. Am. Soc. C.E., Active Member.

Read May 1, 1897.

This bridge consists of a trestle approach of about 2,124 feet on the Pennsylvania side, two 533 feet fixed spans near the Pennsylvania shore; then follows a 323 feet drawbridge and another 533 feet fixed span near the New Jersey shore. On the New Jersey side is a trestle approach of about 324 feet length, making the total length of the structure 4,400 feet over all. All the river spans, of course, are through spans. The bridge carries a double-track railroad.

The steel work was got out in accordance with specifications and strain-sheets furnished by the Pennsylvania Railroad, and under direct supervision and subject to the approval of Mr. W. A. Pratt, Bridge Engineer of said Company. In our Pencoyd office, our Chief Engineer, Mr. C. C. Schneider, had, of course, the direct supervision of the work.

Open-hearth steel was used throughout. Medium steel, with $\frac{3}{16}$ reamed holes and sheared edges, using correspondingly higher unit-strains was used for all the main members of the trusses of the big spans, while soft steel was used in all laterals, in the floor of the fixed spans and of the draw and in the viaducts of the approaches. The same workmanship as for wrought iron was used for soft steel up to a thickness of metal of $\frac{5}{8}''$ inclusive, and the same requirements of workmanship as for medium steel were called for above that.

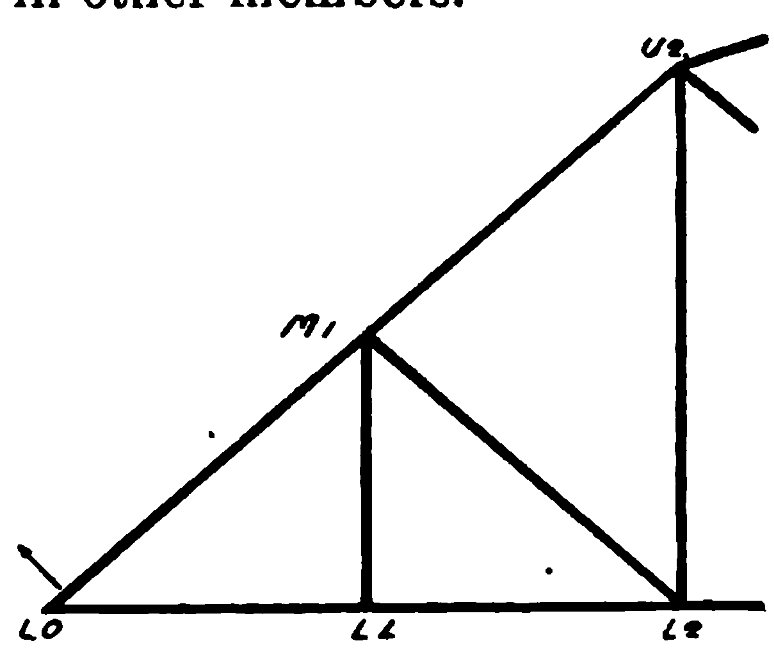
The approaches consist, with the exception of a few street and railroad crossings of irregular lengths, throughout of 40 feet spans and 40 feet towers, with a maximum height of about 49 feet from base of rail to masonry. The columns consist of two webplates and four angles with flanges turned in latticed on both sides, and are well-anchored to the foundations. A one-story bracing,

consisting of struts and stiff diagonals, is used throughout. There are four lines of stringers, 6′ 6″ center to center, and 4′ 9½″ deep. The two outer lines rest directly on the columns of the towers, the two inner lines are supported by cross-girders 5′ 2½″ deep, which are framed between these columns. Objections have been raised lately against a construction of this kind, claiming that the stringers should be framed between the cross-girders. I wish to say, however, that this design was only adopted after all advantages and disadvantages of the same had been carefully weighed against each other. Cost of shop and field work, also time of erection, are largely in favor of a structure as used. The main objection to riveting the stringers between the cross-girders, however, was the difficulty in replacing eventually loose rivets at the expansion joints. We have tried, therefore, to make a thoroughly stiff structure in the way described before, and I must say that, when you pass in a train over it, you will notice so little vibration that you can hardly take exception to the design adopted.

The three fixed spans of 533 feet lengths are arranged in eight main panels of 66′ 7½″, and these are subdivided in two panels each by using a secondary system, giving a stringer length of 33′ 3¾″. The truss height varies from 57′ 0″ at the hip to 84′ 0″ at the center. End floor beams have been used throughout. The chords and end posts have four webs 30½″ deep and cover-plates 46″ inches wide. The sections are completely balanced. At all joints the chords are designed for full pin-bearing, no butt-joints being used. One outer pin-plate always runs over the angles, the other pin-plates being only of the clear width of web between the angles in order to allow the driving of the rivets through the flanges. The inclined end-posts have no field splices. They are 87′ 8$\frac{3}{16}$″ long center to center pins, and have a scale weight of about 96,600 pounds each. Only the covers and webs have shop splices, while the angles and balance-strips are of one continuous length. All posts consist of two webs and four angles with flanges turned in; these have no field splices either, and shop splices in webs only at the center pin. The bulk of the eye-bars are 12″ wide, with 25½″ heads to allow for an 8¾″ pin. The thickest bar used has 2½″ metal, and the heaviest weighs about 5,500 pounds finished. Special attention was given to the packing of the eye-

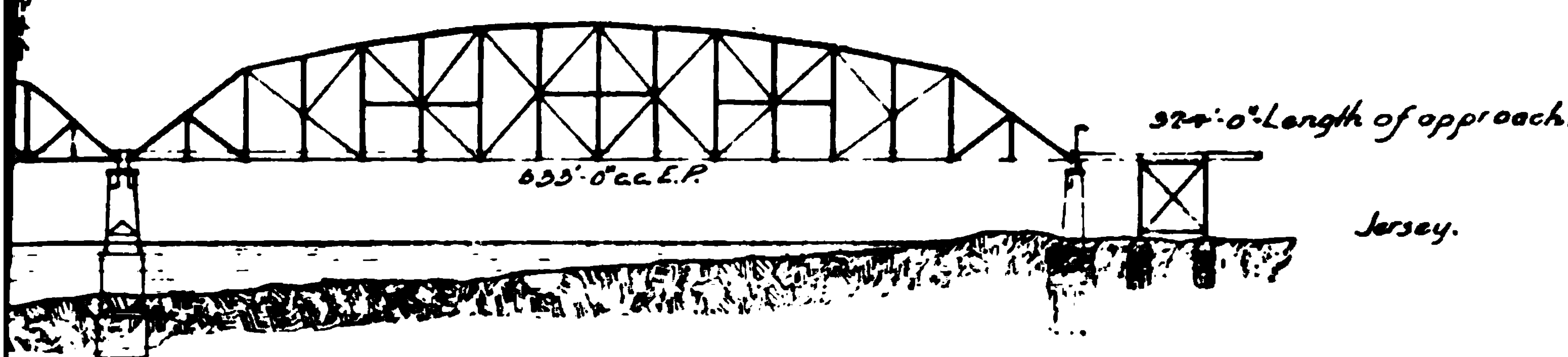
bars. No eye-bar is tapered more than $\frac{1}{24}''$ per foot. This is accomplished by using an unsymmetrical packing of the bottom chord-bars, having nine and ten bars in the panels adjoining the center, ten and nine bars in the panels next to this, until we reach the symmetrical packing of eight bars in the third panel from the center. This allows, at the same time, to utilize the whole space between the posts for the packing of the eye-bars, reducing the cut in the cut-out floor beams to a minimum. A perhaps small matter, but one that probably saved much expense and delay in the field, are the diaphragms in all chords and end-posts to prevent the shifting of the webs towards each other after the pin-holes were bored. In a 2-web chord this is not such a very serious matter, while in a 4-web chord the first two webs guide the pin, so that, in driving, the latter must strike the solid metal of the other webs, if any of these have shifted.

In all trusses with a secondary system the deformation of the structure will throw bending stresses into some of the main members. Let me illustrate this with the end post, where it has more effect than in other members.



If $U_2\ L_2$ elongates it will bend L_0 in the direction of the arrow, the same will occur when $L_0\ L_2$ elongates or $L_0\ U_2$ and $M_1\ L_2$ compresses. In our case this would have thrown M_1 0.8 of an inch out of the line $L_0\ U_2$, which would correspond to about 3,900 pounds per square inch fibre stress from bending, a stress for which, to my knowledge, never any allowance has been made in former designs of a similar kind. This extra stress has been avoided on the Delaware Bridge by shortening the eye-bars $L_0\ L_1$ and $L_1\ L_2$ one-half inch each or one inch total, thus bend-

DELAWARE-RIVER BRIDGE, NEAR BRIDESBURG, PHILA., P. & N. J. R. R.



ing the end post ⅞ inch the other way for bridge unloaded and making it practically straight under its maximum load. The chords and main posts have been treated in a similar way, so that we can say that all members in this structure are practically straight and free from bending when they get their maximum stresses. Thus all unnecessary bending stresses caused by the secondary system are avoided in the trusses.

The lateral bracing is stiff throughout; deep sway-braces have been used at all main panel points, while at the secondary panel points a top strut only of the depth of the chord was used. The stiffness of the continuous, wide hangers was considered sufficient to prevent any undue vibration at these points, and it was thought preferable to use less, but good and strong braces in order to preserve the clear outlines of the structure and to do away with that mixed up impression a bridge is likely to make when too many light pieces are used. The same principle was followed in designing the deep portals. A new detail you see in the top strut of the same. This consists of two webs as deep as the chords and under right angles to the end posts and first top chords, with two angles each and a bent cover on top and bent lacing at the bottom. Square connections were thus made possible with the top laterals and the portal diagonals, all of which consist of four angles latticed as deep as the chords. The bottom lateral system is stiff throughout, and is rigidly connected to the foot of the posts and the cut-out floor beams at the panel points and to all stringers in between.

At the end of each truss a reaction of 1200 tons had to be taken care of. A set of seven 15″ I-beams 8′ 2½″ long, with diaphragms riveted in between, runs transversely under each shoe and also carries the end floor beams. Below this set is one of thirteen 12″ beams 5′ 2″ long running longitudinally. These rest at the fixed ends on another set of seven 20″ I-beams 8′ 2″ long parallel to the first, which are cut in the middle and framed into a 20″ x ¾″ plate, which acts as a brace against overturning. At the expansion ends, the 20″ beams are replaced by seven segmental cast-steel rollers of 18″ diameter, 8½″ wide and 8′ 2½″ long. To prevent these rollers from leaving their normal position, the middle roller has at each end, top and bottom, a gear tooth 7″

long, which is guided properly in the bottom plate below and in the shoe above. The usual construction of a longitudinal center strip with sufficient rivets to take care of the wind, etc., prevents the spans from shifting sideways. The deep roller-nests are very sensitive, and therefore relieve the masonry greatly of strains caused through the contraction and expansion of the trusses. When assembled in the shop, one man could easily move the whole nest, even though its weight was something like 26,500 pounds.

To the deflection and camber of these spans was given special attention. At the center of the bottom chords the deflection figures as follows:

0.679″ from play in pins,
3.520″ from dead load,
4.199″ when swung but unloaded.
3.401″ from live load.
7.600″ total.

The shortening of the bottom chord-bars $L_0\ L_1$ and $L_1\ L_2$ mentioned above cambers the span. For the same purpose all top chords (the main panels of 66′ 7½″ I mean) were lengthened ⅜″ each. A very uniform camber was thus obtained, raising the center 5 89″. This leaves after the span is swung the bottom chord at the center 1.691″ above normal for bridge unloaded and brings it 1.710″ below for bridge loaded. As it will hardly ever occur that both tracks of the bridge will be loaded at the same time with the maximum load for the full length of the span, not more than half the load assumed being the usual case of loading, these figures were adopted as final. Actual measurements after the span was up gave practically identical figures:

The bottom chord stretches

0.50″ from play in pin holes,
1.58″ from dead load,
2.08″ total for bridge swung but unloaded.
1.53″ from live load.
3.61″ total.

A change in temperature of 120 degrees will move the roller-end 5½ inches. The rollers were therefore set so that they had to move 2.08″ to get in their normal position when the blocking was removed, and they were designed to allow a fair margin over a total motion of 5.5 + 1.53″ or about seven inches, or 3½ inches plus or minus.

In the usual way of construction the total stretch of the bottom chords of 3.61″ caused by the play in pins, by the dead load and by the live load will also go into the stringers and the lower laterals. The floor beams in our case are very rigid, really held continuously by the four lines of stringers. This stretch of the lower chords would therefore throw an exceedingly severe tension on the connection of the outer line of stringers, considerable horizontal shear on the connections between floor beams and posts, and then naturally bending in the posts. To avoid this the floor system was not put in place until the trusses were completely swung, and the stringers were kept sufficiently long to make up for the stretch of 2.08″ from the play in the pins and from the dead load. To provide against the bad effect of the live load stretch of 1.53″ very wide connection angles (6″ x 4″) were used, with the 6″ leg against the floor beam and with one line of rivets close to the outer edge of these angles. This allows for some give in these connections before the strain on the rivets gets too severe.

The draw-span is center bearing with wedges at ends and center. The construction of the trusses, the floor and laterals follows the same line as in the fixed spans. The time I can allow for this paper makes it impossible to give a full description of the machinery, which in a good many instances leads to very interesting problems.

When swinging, the total weight of the bridge, about 2,000,000 pounds, is carried on the center pivot, the eight wheels being only used to balance the draw. The main trusses are carried on heavy cross-girders 6½ feet deep, which through the bolt girders, bolts and I-beams transfer their load to the pivot and pivot-casting. The whole center, consisting of cross-girders, bolt- and wedge-girders, was shipped from the shop riveted up complete, ready to be dropped in place. It made a good car-load of about 82,000 pounds net.

The pivot proper consists of an upper and lower disk of case-hardened steel with a phosphor-bronze disk between them, all of 27 inches diameter. When closed the two center wedges are brought to a tight bearing through a screw and lever mechanism, while at the same time the end wedges which are driven by a worm wheel and lever mechanism, situated at the ends of the bridge, lift the ends ¾ to 1″. This lift is ample to prevent the uplifting of the ends in case of one-sided loading. The bridge thus acts after it is closed, as a continuous girder, as far as the live load is concerned. Of special interest is the latch arrangement. It often occurs, when a draw reaches the closing position with too much velocity and the latch catches too suddenly, that the bridge is brought to a very sudden stop and has to stand an injurious jar. To avoid this, an adjustable counterweight has been provided at the shaft driving the latch, by which the velocity of the fall of the latter can be regulated. The latch-catch is of a peculiar curved shape, on which a small wheel at the end of the latch has to run up. When, therefore, the draw reaches the closing point with a greater velocity than seems desirable, the latch will jump over the catch, and all the operator can do is to bring his bridge to a stop and go back somewhat slower. A very ingenious interlocking system was provided later by the railroad company, making it practically impossible for a train to attempt to enter the draw unless everything is in the proper condition. The draw is reversible, so that it can follow the ship passing through. It is operated by steam power, from the engine house above the tracks, the engine for which, with all machinery above the platform, was designed and furnished by Cyrus Currier & Sons of Newark, New Jersey. Provisions are, of course, made to operate the bridge by hand in case of an accident. With the exception of very few and unimportant parts, where cast iron was used, all castings were made of medium open hearth steel. All steel castings were thoroughly annealed. The wedges have been drawn and the draw opened completely, and *vice versa*, in as short a time as about 55 seconds.

The approaches were erected first in the usual way. The erection of the river spans had to begin on the Jersey side, the stone piers there being ready first. The fixed spans were erected on regular

false-work, while the draw was erected on the fender, as a channel for navigation had to be kept open at all times. After the first span was up, false-work was put in the two openings of the draw, and in the first two 66 feet panels of the next fixed span. The traveler was moved over on this latter portion. Meanwhile, navigation had to go through the open part of this fixed span. Then the false-work in the opening of the draw next to the Pennsylvania shore was removed and this channel opened for navigation. The false-work in the channel of the draw next the Jersey shore had to stay in place, as the material for the draw span had to be brought over the same. This done, false-work could be put in, covering the opening of the two fixed spans next the Pennsylvania shore, to allow the material for these spans to come in from this side. The erection was then started on the second span from the Pennsylvania shore. This long stretch of false-work, in conjunction with the, about 800 feet long, fill from the Pennsylvania shore, which carried the trestle, in order to reach the new bulkhead line, caused a serious ice gorge. This ice gorge caused sufficient alarm to make it seem advisable to remove all the eye-bars, etc., of the second span, that had just been stretched out on the false-work, to a place of greater safety. Fortunately, warm weather set in and broke up the ice. It was found, however, that the false-work had been pushed down river from 10 to 12 inches. Another severe test the false-work had to stand was at the time of the heavy storm that caused so much havoc in our city and surroundings in the early spring of 1896. It passed right across the bridge when one span was partly up and the high traveler was also carried by the false-work. It did not do any serious damage however, but pushed the whole structure about four inches up river.

One bent of false-work was put under each panel point, making the bents about 33 feet apart. The bents had two stories. The lower story had 10 vertical and two battered piles within a minimum diameter of ten inches at the river bottom. They were driven according to the Pennsylvania Railroad Company's specifications for pile driving used for the foundations of the approaches. They were well braced down to the low-water line, that is, for the upper 15 to 18 feet, according to grade. The maximum

height of this lower story above the bottom of the river was about 58 feet, leaving 40 feet unsupported below low water line. The upper story of 32 feet was made up of ten 12 x 12″ timbers, well braced with a 12 x 16″ and a 12 x 8″ cap on top. The track in the middle was carried on the cap by pony bents about 10 feet high, which brought us up to the final elevation of the rail. The traveler was carried on each side on four lines of 20″ I-beams, 64 pounds per foot, while the track was carried by a 20″ 64 pounds beam, reinforced by 8 x 16″ timber per rail. 8 x 16″ timbers carried the plank for the working platform.

The traveler was constructed of steel. It had three bents about 33 feet apart to cover one main panel of the trusses. Each foot of the bents was supported by a car truck. The frames of these bents were made very rigid crosswise, being riveted throughout, while the longitudinal bracing was made as light and flexible as safety would permit, to allow for some give in the structure in order to make provision for the irregularity of the track. The total height of the traveler was about 110 feet, which makes its top about 210 feet above river bottom or about 170 feet above low water line. It was about 46 feet wide center to center of trucks at the bottom and 81 feet wide on top. The platform on top was supported by ten longitudinal lines of 20″ I-beams, 64 pounds per foot, and a sufficient number of loose cross-beams of suitable strength were provided to carry the steel work during erection. It enabled the simultaneous hoisting of two end posts of a total weight of about 96 tons, while the other members adjoining this were held in position. The total weight of the traveler without trucks was 292,000 pounds.

Let me give you a few figures covering the weight of the steel

The Jersey approach of 324 feet length			574,000	pounds.
The Pennsylvania approach of 2,124 feet length			3,831,000	"
			4,405,000	"
Three fixed spans, 4,182,000 pounds each			12,546,000	"
The draw-span with riveted work	1,505,000	pounds.		
Machinery	356,000	"		
	1,861,000	"	1,861,000	"
			18,812,000	"

DISCUSSION.

James Christie.—A notable feature of this bridge was the brief period that elapsed during its construction, and this serves to illustrate the rapid methods of handling material, that have become usual during latter years. The length of spans was not remarkable, as longer spans have been erected in this country, but the magnitude of many individual parts was unusual. For example, the end posts, weighing nearly fifty tons each, were finished and handled in units. Eye-bars, 12 x 2¼ inches, and 56 feet long, weighing 5,500 pounds each, were produced from steel blooms 12 inches square and 12 feet long. There were several novel details, which Mr. Wolfel has described. I would commend the method of bracing the webs of posts and top chords to prevent distortion of section in handling. This preserved the alignment of pin-holes, and saved much trouble in the insertion of the large pins, a frequent cause of serious delay. Placing an initial bend in the end post by shortening the first panel of the lower chord, was a good conception. The proper thing to do in all structures, is to arrange for the component members to be in the best position to resist strain, when the deflection due to maximum load has occurred. I well remember in the early days of iron bridge building, the trouble that was sometimes taken to bevel the joints of top chords, to allow for the camber. This was all wrong, the joints should have been square, and the joint would then be in the best shape to receive maximum compression, when the camber disappeared. The substructure of this bridge would form a subject for a very interesting paper. Probably the President could bring forward something relating to the foundations.

Jos. T. Richards.—I believe it is the intention to have a paper read before this Club, giving an account of the masonry. It was sunk down 70 feet below water, if I remember correctly, and the work was accomplished in a remarkably short time. I have a memorandum here that states orders were given to go ahead with this masonry on January 15, 1896, and the last stone was laid on November 1, 1896. Much bad weather occurred during that time. The flooding of the piers in position, storms and heavy

tides were experienced. The time would have been shorter if there had been constant good weather. Twenty thousand cubic yards of granite masonry were laid, and some of the coping stones weighed 22 tons. Both speed and economy are in evidence. I hope we shall later have a paper on the masonry.

EDGAR MARBURG.—There is one feature to which I would like to call attention, and that is the pin-bearings of the top chord. The usual practice is to provide butt-joints, that is, planed bearings, between adjoining chord members. To make full pin joints, as in this instance, means much additional material and workmanship. To what extent that is warranted is open to debate. The prevailing practice is to rely on butt-joints throughout the top chord, except at the hip joint. I would like to ask also whether observations have been made as to the deflection of the truss as a whole; if so, how closely it agreed with the calculated deflection, and whether at the same time any delicate observations were made on the opening of the top chord joints to see whether any movement took place at these points, or whether this local movement was too minute to be noticeable.

MR. WOLFEL.—They had this checked very closely, and the deflections came out practically identical with the calculations, about $\frac{1}{16}$ inch. To the second question, I was myself against those pin joints, and they bothered us, but it was insisted on. There is no possibility of the chords moving around the pins when loaded, but it is an excellent thing to have pin joints, as they do away with all secondary strains caused by possible inaccurate workmanship in the forming of chords. We do away with all bad effects of inaccurate workmanship. No observation was made as far as the movement goes.

F. SCHUMANN.—The time of erection of that bridge was wonderful. It is hard to realize that such a thing could be erected in so short a time. We can realize what elaborate arrangement must have been made to make it possible. I would like to know the deflection of those friction-disks, and also if pilots were used in inserting the pins.

MR. WOLFEL.—About 5,500 pounds to the square inch. When those disks are made they have to be ground together, and great care should be taken that they have a little more

bearing in the middle. We once built two draws on Long Island, and one turned round very easy, but the other would hardly turn at all. It was decided that the trouble must be with the disks. The disks actually wore on the outside and wedged themselves tight. There is special care now taken that the disks bear slightly more in the middle than on the outside. Pilots were used in inserting the pins. Some were made of soft and some of medium steel. All the members taking actual strain in the main trusses were made of medium steel. Lattice bars, etc., laterals and flooring were made of soft steel.

IX.

DISCUSSION ON MODERN HIGH OFFICE-BUILDINGS.

May 15, 1897.

THE discussion was opened by Mr. James Christie, who re-regretted the absence of several other members who were expected to take part.

The subject is understood to mean buildings in which the construction is essentially metallic, overlaid with other materials. The modern office-building has gone through a state of evolution, and reached the condition of "definite coherent heterogeneity." In discussing the subject, all parts of the building, from the foundation to the roof, should be considered, including the elevators, heating, lighting, etc. Regarding foundations, the nature of the soil is very important, and different methods of treatment are necessary to adapt it to the load to be supported. Building laws should not only provide for the load to be supported in different soils, but should also consider the sub-soil. Soil of variable character should be made uniform, to secure equal settlement.

In the superstructure, the first element to be considered is the metallic column which carries the other parts. The columns should be of malleable metal to support the bending strains, which are not always capable of structural analysis, as they come from many different causes. The strength of columns is threatened by the liability to corrosion, which is not very great on the interior, but becomes quite important just inside of the casing walls. The columns should always be treated to prevent this danger, and probably the best way would be to enclose them and to fill the inside with concrete. Component parts should be rigidly fastened, so that strains may be evenly distributed.

Floors should be of fireproof construction, and for this purpose brick arches of short spans have been superseded by lighter hollow tiles of longer span. Several ingenious systems are extensively used, in which metallic webbing is incorporated in cement concrete, acting as an auxiliary to the latter.

The roof is probably next important to the foundations, for it serves not only as a cover, but as an essential to the bracing of the building. The partitions in most buildings are dependent upon the openings required for windows and doors, but if well planned, they can become important braces, and should generally be of a cellular web construction. The curtain, or outside wall, is carried by each door as a veneer over the iron work, but it should be strong enough to effectively aid in resisting lateral vibration. The inside work (including lighting, heating and ventilation) is passed over as being common to all large buildings. The elevator has grown with the modern office-building, of which it is a necessary feature; it should be quick, strong and guarded against accident, by the best safety-devices.

JOSEPH T. RICHARDS.—The foundations of Broad-Street Station were criticised as being necessarily broad and heavy, but they have resulted in supporting that large building without any settlement. In the inspection of stone-arch bridges of the Pennsylvania Railroad, I find that if the pier and abutment foundations are on rock, the arch is very durable. Many old arches, made of rubble masonry but with rock foundations, are still intact, while with foundations not on rock, though they may be of the best cut stone, carefully laid, there has often been settlement, and sometimes a failure of the arch. (Mr. Richards then described, with the aid of a blackboard sketch, the usual foundations for plate-girder railroad bridges, crossing streets in cities).

MR. CHRISTIE.—A few years ago, the New York Central Railroad found a weakness in the masonry of some iron bridges, due to the concussion of trains. The matter was remedied, in some cases, by constructing heavy floors for the bridges, which acted as an anvil between trains and masonry.

ARTHUR FALKENAU.—In the foundations for modern office-buildings, the requirements are peculiar, on account of the smallness of the base, in proportion to the height of the structure. With a great load on a small area, every precaution must be taken to secure a sound foundation, and to have the walls plumb. In one instance, a building, twenty-six stories high, is entirely supported on jackscrews, by which any settlement in the foundation can be compensated.

In some parts of New York City, bed-rock lies a considerable distance below water-line. To reach bed-rock in such cases, caissons have been sunk. Difficulty has been frequently encountered in digging for foundations, when adjoining buildings were underpinned with needles in the ordinary manner. The superincumbent weight of the buildings caused the soil to flow from under them into the excavation. In one instance, the attempt to attain the required depth had to be abandoned, as the soil rose almost as fast as it was excavated, and to prevent serious danger to the adjoining building, the floor of the excavation was rapidly and heavily cemented over. A comparatively new method, which avoids this danger and has been successfully applied in New York, is the underpinning of walls before any excavation is made by driving piles of iron pipe to bed-rock. These are sunk in short sections, screwed together, and then filled with cement, thus forming columns, on which the wall rests. Thus the support of the wall is entirely independent of the surrounding soil, which is not the case with ordinary underpinning.

MR. RICHARDS.—I recall a case in our practice, in which rock foundations could not be had short of one hundred feet below the surface of the ground, wooden piles were driven to an intermediate stratum of about four feet of sand. They were then cut off four feet below surface, capped with timbers and brick buildings erected thereon, which have stood remarkably well. The sand strata was about fifteen to sixteen feet under the surface of the ground.

T. H. MUELLER.—I have found that the water under ash-filled ground is generally decidedly alkaline, and while old timbers which evidently had been in the ground for a long time when the excavations were made were very hard, I would like to know whether any member has experience with yellow pine piles under such circumstances. I suspect it would be harmful to metal construction, while it may improve some wood.

COMMUNICATED DISCUSSION.

WM. COPELAND FURBER.—An important and interesting detail in the design of an office-building, which is sometimes overlooked

and frequently given but secondary consideration at the hands of the designer, is that of cost, or, more accurately speaking, economic cost. The economical construction of an office-building is one that concerns the tenant almost if not as much as the owner. The tenant pays interest, in the form of rent, on the money invested in the structure, and therefore true economy in construction is a matter of great importance to him.

By economy is meant the useful adoption of means to an end; the correct design and construction of the frame work, with careful regard to its strength and durability; the preservation of the skeleton from decay, by use of the best known methods, avoiding reliance on paint and similar perishable materials or covering; the selection of suitable materials properly proportioned for walls and foundations; the use of materials only which best retain their usefulness and appearance under ordinary wear, and which admit of refinishing or repair to their former condition with the least expense; the avoidance of extravagance and useless expense in finishing, and the correct design of the mechanical installation with regard to economical operation and subsequent maintenance.

Some designers of buildings permit or allow a building to cost just as much as the owner is willing to spend, overlooking and ignoring the fact that for all useless and unjustifiable expenditures he is laying the burden upon his client and the tenants, who are compelled to pay interest for no useful purpose, seemingly failing to realize that such methods are against public policy, and that all money or labor uselessly spent impoverishes the community to just that extent.

As the office building occupies a semi-public function, its design and operation is therefore a matter of public interest.

Many of the New York and Chicago office-buildings are designed with little thought to the economic commercial cost, and the money invested in them, over and above their economic cost, can be justified from no rational standpoint.

The limit of cost permissible for any structure of a commercial public nature, can be readily obtained by considering the factors of permissible cost of site, permissible cost of building versus the mininum rent which can be expected or demanded for satis-

factory service based on the economic value of the service rendered, less the cost of operation and maintenance.

The value of the rent to be obtained is governed like all other commodities by the cost of furnishing the service and a fair interest on the cost of the investment, etc.

Buildings in which the investment is too great or out of proportion to the service rendered, are the first to feel the readjustments which are always taking place, owing to the shifting centers of business activity, convenience or desirability of location, cost of service, etc., so that money needlessly or extravagantly expended in such structures is withdrawn for use and practically wasted, as it cannot be adapted to other useful purposes or employed in profitable enterprise and is therefore a public wrong.

The conscientious designer should bear in mind that all interests are best served, and that he is rendering the most valuable assistance to his client and the community, when he seeks to preserve in his work a proper balance between the commercial requirements and the artistic possibilities.

X.

THE BERTRAND-THIEL MODIFICATION OF THE OPEN-HEARTH PROCESS.

By J. S. Robeson, Active Member.

Read June 5, 1897.

I have always felt that the man who offered an apology before reading a paper was very like the man who hesitated—he was lost. Lost or not, however, I feel I must say that entirely through my own fault I failed to notify the committee of the possible length of this paper and, as a consequence, I have the honor of dividing the evening with Mr. Codman. For this reason my remarks will be as brief as possible, and I will touch but lightly on certain theoretical points which could easily be greatly elaborated.

This modification of the ordinary open-hearth process has already been very ably described by Mr. Joseph Hartshorne, with special reference to the commercial results, in a paper read before the American Institute of Mining Engineers, at the Colorado Meeting in September, 1896. It has also been described, with much detail as to theory and possible theoretical results, at the Middlesborough Meeting of the Cleveland Institution of Engineers by Mr. Percy C. Gilchrist. Mr. Ernst Bertrand, one of the inventors, submitted some further notes on the process at the last meeting of the Iron and Steel Institute, and Mr. Otto Thiel, the other inventor, has presented quite a complete study of it before the "Verein Deutscher Eisenhüttenleute," which was published in *Stahl und Eisen* of May 15, 1897.

The very remarkable results that are being obtained by this process, together with the interest aroused among the steel makers of Europe and this country by the above papers and the discussions of them, has led me to believe that a general description of the method, together with some detailed facts in connection with it, would prove of interest to the many users of steel connected with this association.

Messrs. Bertrand and Thiel were connected with the works of

the "Prager Eisenindustrie-Gesellschaft," where this process was developed, as General Manager and Superintendent of Steel-Works respectively. The plant is situated at Kladno, near Prague, in Bohemia, where the process is now in daily operation. This plant has been noted for a number of years for the very high grade of steel produced there by the basic Bessemer process. It has also been marked by close observers for the many advances in small details of practice, from the mining of the ore and coal to the rolling of the finished material.

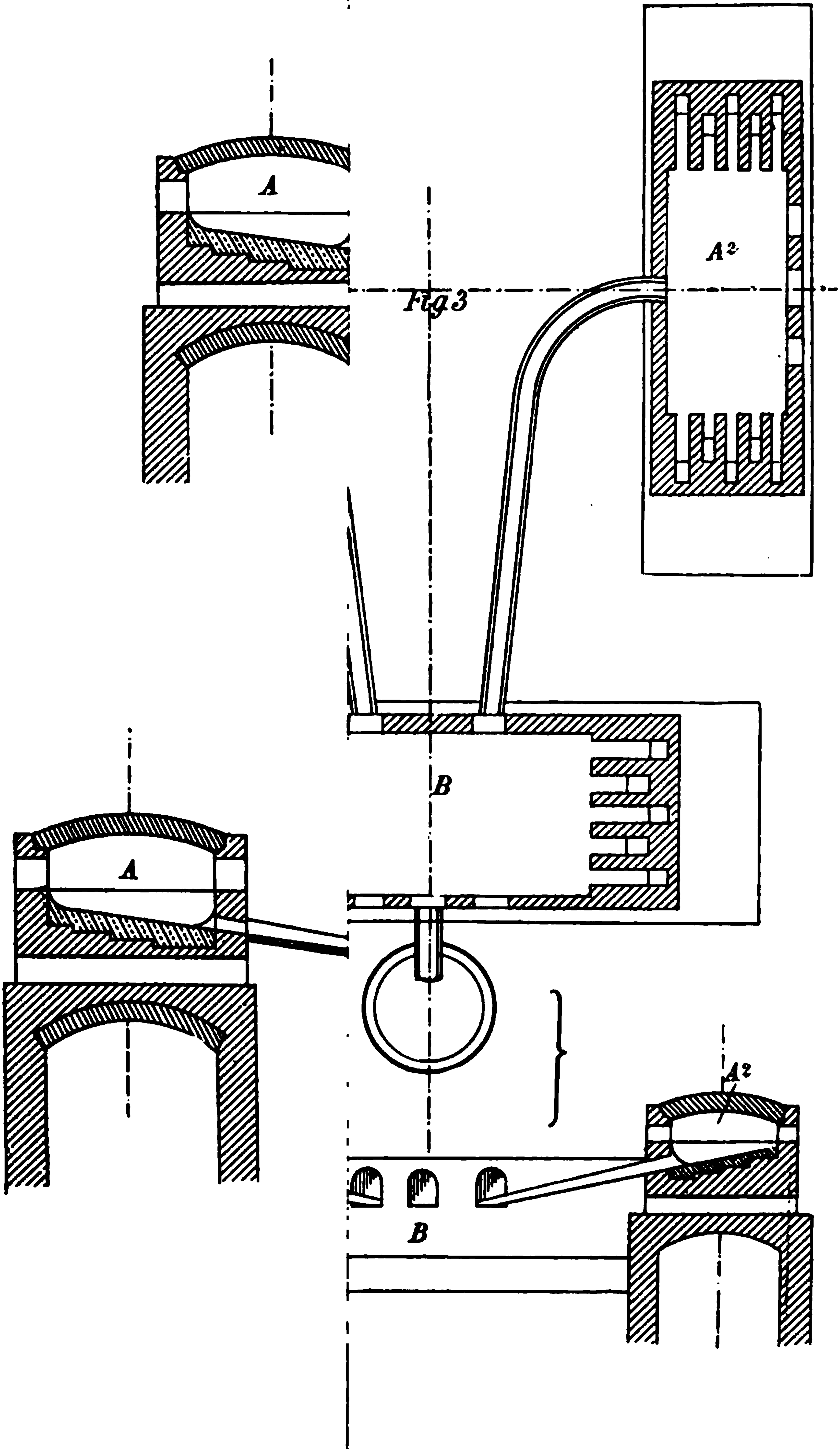
The company owns and operates coal and iron ore mines, limestone quarries, a basic Bessemer and an open-hearth plant, finishing mills for rails, plates, shapes, rods, etc., together with all the necessary adjuncts of such a plant. The poor coal available in this locality, together with other reasons, rendered it advisable to adopt other means than the cupola for melting the iron to be used in the converters, and open-hearth Siemens furnaces were installed for this purpose. They were of from 10 to 12 tons capacity and were placed upon a higher level than the converters, so that the iron might run down into the latter through a trough.

As the production and demand for open-hearth steel increased it was but natural that one of these melting furnaces should be used for making steel.

This was done and such steel was successfully made and cast from the ladle on the locomotive crane used for the Bessemer, even though it had to be run through a trough 90 feet long.

Owing to the increasing demand for open-hearth steel, an additional furnace of larger capacity (20 to 22 tons) was built, and this, of course, was placed quite close to the track, so as to do away with the long trough. Thus there was one furnace, of 10 to 12 tons capacity, on a higher level and behind a furnace of say 20 to 22 tons capacity.

Some time during the fall of 1895, it became necessary to cut down the bottom of the smaller upper furnace, now known as the primary furnace, and it was accordingly charged with gray (*i. e.*, siliceous) phosphoric pig-iron. When this was melted and in a fit condition to tap, though not finished steel, some samples were taken of the metal and analyzed.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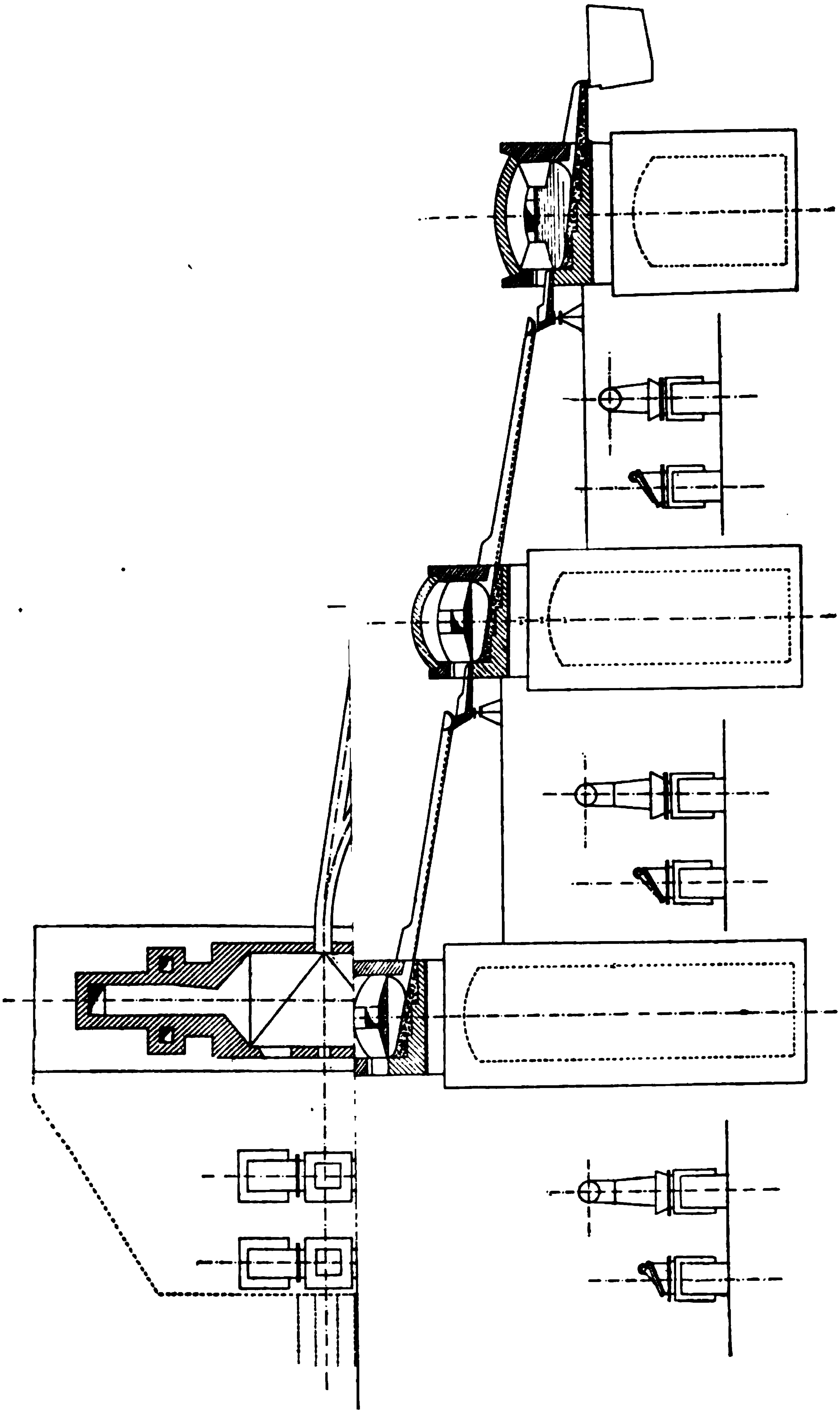


The results were such that much discussion was aroused as to whether it would not be advisable to divide the initial charge of pig-iron and scrap into parts, putting the more impure material (*i. e.*, the pig-iron) with the proper proportion of limestone and ore into the upper furnace, and the purer material (*i.e*, the scrap), with just a sufficient amount of limestone to form slag, into the lower or secondary furnace and then, when both were molten, to run the metal from the upper into the lower furnace, while holding back the dirty, impure slag. This was tried and most remarkable results were obtained.

Using Mr. Bertrand's own words, the process may be briefly described as being "based upon the principle of dividing the work heretofore done in one furnace alone between two or eventually three furnaces, and of perfectly separating the resulting phosphoric and siliceous slags from the metal as it passes from one furnace to the other," and again . . . . "the heats absorbed considerably more time towards the finishing of the heat (when only one furnace was used) owing to the necessity of adding much more lime for the neutralization of the resulting more phosphoric and siliceous slags, as it took some time to free the metal effectually from the phosphorus."

This fact appealed probably much more strongly to Messrs. Bertrand and Thiel, at the time when they began to use this process, than it would have done to our makers of basic open-hearth steel, because in Austria they were compelled to use a pig-iron higher in phosphorus than the metal used here.

Very many tons of so-called basic open-hearth steel have been made in this country, when the operator simply melted pig-iron and scrap, both within or very close to the Bessemer limit in phosphorus, on a hearth composed of a basic material. Under these circumstances the slag was never impure, there was never very much of it, and it was impossible not to eliminate the phosphorus.

Pig-iron containing 0.5 per cent. and over of phosphorus is in some districts much cheaper than that which is within the Bessemer limit of 0.10 of a per cent. and is everywhere more plentiful, I think; and scrap of a varying and unknown content of phosphorus is certainly more cheaply and easily obtained, so that to-day the steel maker who wishes to find a market must

seek and use not only the cheapest material but the best method of manufacture.

To both of these points the Bertrand and Thiel process lays claim.

On the score of cheapness, the cost of the metals just referred to comes in, but this is not inherent to the process, since these same metals can be used on the ordinary basic open hearth, but when they are so used, as they must be to-day, the advantages of the following points are more marked than when the higher-priced low phosphorus mixture, employed by many heretofore, is considered.

In 1896, Mr. Hartshorne showed that with a mixture of about 40 per cent. of pig-iron, containing 2.5 per cent. of phosphorus, and of about 60 per cent. of ordinary steel-scrap, these two furnaces at Kladno were making from five to six heats of 22 tons of metal charged in twenty-four hours, or say 110 to 132 tons. If these furnaces had been run separately, in the usual manner, with a similar mixture, they certainly would not have made over two and a half heats each in the twenty-four hours, or say 80 tons. This shows a minimum gain of 30 tons, or 37.5 per cent. Later, in 1896, Mr. Bertrand in a personal communication says that he is making from 29 to 30 heats per week, or five per day, with a mixture containing over 60 per cent. of pig-iron. (Average product = 100 tons per day.)

With such a proportion of pig-iron these furnaces working in the ordinary manner could certainly not make over two heats in twenty-four hours, or 60 tons, and here we have a minimum gain of 66 per cent.

Mr. Gilchrist, in his experimental heats with the process, was aiming to find out whether it could be worked to advantage when using 100 or nearly 100 per cent. of highly siliceous and phosphoric pig-iron. Though his results were most satisfactory, still they did not show any such marked speed as that shown above. Mr. Bertrand thought that this was probably caused by the inexperience of the workmen with such pig-irons and mixtures. This seemed quite probable and has since been proven true, since, under date of May 12th, he sends the following data of several heats made for and in the presence of an English ironmaster.

		Pig.	Scrap	Ore.	Lime.	Analysis.					Time.	
		Tons.	Tons.	Kg.	Kg.	C	P	Mn	Si	S	H.	M.
Charge No. 685	Primary Furnace	7½	5	500	300	2.6	0.9	0.7	0.6	.03	4	40
	Finishing Furnace			900	600	1.4	0.7	0.5			1	50
	Steel					.11	.02	.34		.05		
Charge No. 693	Primary Furnace	9½	2½	1700	300	2.8	1.2	0.8	0.8	.03	5	10
	Finishing Furnace			800	650	.89	.36	.03			1	20
	Steel					.10	.009	.37		.05		
Charge No. 715*	Primary Furnace	11		1700	800	3.6	1.6	1.0	1.0	.05	4	05
	Finishing Furnace			1100	860	2.6	.31	.02	0.1		3	45
	Steel					.09	.01	.32				
Charge No. 722	Primary Furnace	11	1	2000	800	3.3	1.4	.93	.9	.03	5	10
	Finishing Furnace			900	620	1.5	0.2	.03	.06	.05	2	05
	Steel					0.2	.01	.51				
Charge No. 790	Primary Furnace	11	1	2000	800	3.3	1.4	.93	.9	.03	5	20
	Finishing Furnace			800	250	1.43	.13				1	00
	Steel						.04					

* The analysis of the metal going into the finishing furnace shows high carbon, thereby explaining why this heat lasted so long in the finishing furnace. Had more ore been added in the primary, the heat would have been finished much quicker.

These heats show an average of less than five hours each in the primary furnace or four heats in twenty-four hours, and in the secondary furnace of two hours each. This shows at once that the secondary furnace, even without excepting heat 715, as explained in the note, could handle the output of two primary furnaces, or eight heats equal to 96 tons in twenty-four hours.

If two furnaces like the primary and one like the secondary were run independently, we could not expect more than two

heats each twenty-four hours from each furnace, or a total of 80 tons. If run on the Bertrand-Thiel process they would yield 96 tons, a gain of 20 per cent. in output even when using from 60 to 100 per cent. of highly phosphoretic pig-iron.

It must be plainly evident to the most superficial observer that such an increase of production per furnace, as has been shown, would result in a decrease in every item on the cost-sheets, and an examination of the details of the Kladno results confirms and explains this at once.

Any discussion of the coal used for heating, steam or melting purposes would be out of place, since the ordinary result of an increase of product per day in any of the usual type of furnaces will, perforce, result in such a decrease.

The decrease in the consumption of limestone, according to Mr. Hartshorne's figures, which by the way are compiled from the original cost-sheets of this plant, is 52.68 per cent.

This results from the fact that the limestone added is brought into direct and close contact, on account of the comparatively small bulk of metals present, with the impurities which it is designed to remove and that consequently none of it is wasted on account of being unable to reach these impurities, owing to the thickness of the slag.

Besides the actual saving of money from thus using less limestone, the fact that less is used shows at once that a smaller bulk of slag is produced, hence less fuel and time has been required for its fusion. Again, the loss of metal will be less, both because of the increased speed of operation and the smaller bulk of slag present.

This proportionate increase in output also decreases the consumption of magnesite or dolomite necessary for repairing the hearth, and thus the time required for so doing, and also increases the life of the roof, ports and walls of the furnace.

These two results are obtained for exactly the same cause. The output being thus increased means simply that the heats remain a shorter time in the furnaces, and as the molten metal in the primary furnace is never maintained for any length of time at the high temperature required for soft steel (its composition when tapped being about 1 per cent. C and 0.5 per cent. P,

it follows that this furnace is subjected to very much less wear and tear. The secondary, or lower furnace, has to withstand the high temperature for the finishing of the steel, but as the metal is maintained at these high temperatures for a much shorter time than in the ordinary practice, the wear and tear is here also reduced proportionately.

The saving in basic refractories according to the Kladno cost-sheets, as given by Mr. Hartshorne, is 57.1 per cent. and in the acid refractories 47 per cent.

Now these results are just such as can be obtained when working under the practice most commonly known in this country, *i. e.*, using from 50 to 60 per cent. of scrap and from 40 to 50 per cent. of pig-iron, but, Mr. Bertrand, over two years ago said, "Still the greatest advantage of this new method of working lies no doubt in the possibility of working with almost any kind of pig-iron that may be had cheaply, no matter if it be high or low in phosphorus, or if it contains more or less silicon."

The profit of the process lies, as you know, not only in the possibility of reducing the cost of manufacturing by saving lining, fluxes, fuel, etc., and increasing the output, but also, and often to a greater extent, in the possibility of dealing with almost any kind of pig-iron, *i. e.*, in using such lower-priced materials, and still making from them the finest qualities of finished products.

This point has been clearly proven by Mr. Gilchrist's series of heats, and in addition he has brought out the fact that the C, Si, and P in the pig-iron act as reducing agents on the iron ore, and that as a consequence the gain of metallic iron from the ore necessarily charged nearly and in some cases more than equals the natural loss, *i. e.*, from the oxidation of the C, Si, P and Mn contained in the metals charged.

Whether or not the cost of the ore, or the metallic iron contained therein, be charged against the furnace, it is of course cheaper to employ the reductive power of these elements (in order to gain the iron in the ore, which must be added for the sake of the oxygen) than it is to put the same ore through the blast furnace, and the balance from this reaction unquestionably will always be found on the right side of the cost-sheet.

Just how far this can be carried, how much pig-iron should be

used, and what percentage of carbon, silicon, and phosphorus it should contain, is not yet clearly determined, and must always be largely a question of local conditions as to the comparative costs of scrap and pig-iron.

In England, where scrap is scarce and very high, while siliceous, phosphoric pig-iron is cheap, the advantage of being able in this manner to work so rapidly with pig-iron alone is very marked.

Steel containing from 0.06 to 1.25 per cent. carbon can be and has been made with great regularity, and the phosphorus is under as good, if not better, control than in the ordinary basic open-hearth.

The elimination of all the elements is so very rapid and the effect of introducing the molten metal free from slag from the upper primary furnace into the heated hearth of the lower secondary furnace being to produce a violent reaction, there follows a very complete reduction of all the oxids, together with an elimination of the gases, so that very compact and solid ingots are made, reducing the faults and cracks during the rolling, and yielding a very fine finished product.

XI.

OBSERVATIONS ON RAIN-FALL AND STREAM-FLOW IN EASTERN PENNSYLVANIA.

By John E. Codman, Active Member.

Read June 5, 1897.

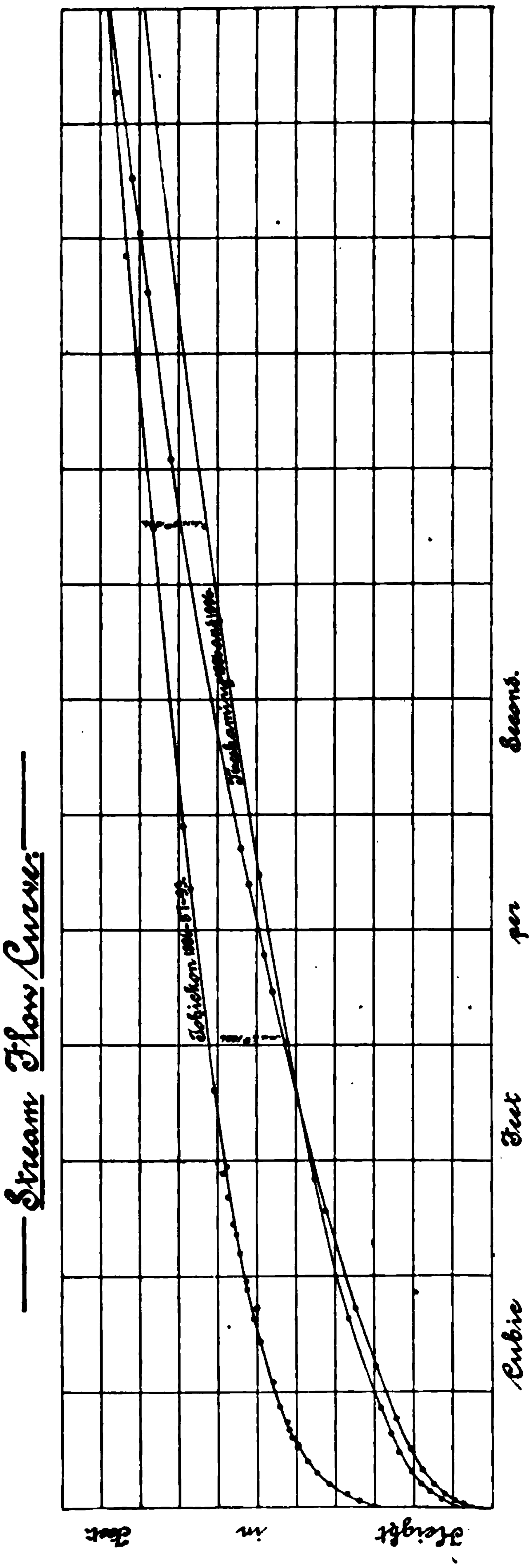
For the past fourteen years the Philadelphia Bureau of Water, Department of Public Works, has maintained a continuous series of rain-fall and stream-flow observations on the three following creeks, viz.: the Perkiomen, one of the main tributaries of the Schuylkill River; the Neshaminy and Tohickon, tributaries of the Delaware River. This paper will discuss, from these data, the quantity of water available from a given watershed, either as a source of water-supply or water-power. The quality and purity are subjects for another line of investigation.

The areas of the watersheds directly under observation on each stream are: For the Perkiomen, 152 square miles; for the Neshaminy, 139.3 square miles, and for the Tohickon, 102.2 square miles. The watersheds of the three streams are contiguous to each other, and form a combined area of 393.5 square miles above the gauging-stations. All of this area is within the geological formation known as the New Red Sandstone.

The duty of collecting and recording the hydrographic data obtained has been under my charge for the past ten years. Previous to this, the work had been carried on in connection with the surveys for a future water-supply for Philadelphia, under the charge of Rudolph Hering.

Complete and accurate surveys and maps of the watersheds of the Perkiomen, Neshaminy and Tohickon creeks, showing contours every 5 feet, roads, wooded and cultivated lands, farm houses, mills, etc., were prepared and published by the Pennsylvania Geological Survey.

Up to the present time very few data of this kind have been available for the use of the engineer. The most complete work published by state authority is the New Jersey Geological Survey, Vol. 3, by C. C. Vermeule. No records of stream-flow were



The ordinates represent differences of 100 cubic feet, beginning with zero at the left hand; the abscissas represent differences of 0.5 feet, beginning with zero at the bottom.

taken by the Geological Survey of Pennsylvania. New York has a series of about 18 years on the flow of the Croton River. Massachusetts has a series of about 22 years on the flow of the Sunbury River. The United States Geological Survey has published within the past year or more a large amount of hydrographic observations, mostly on western rivers.

The streams under observation have a rapid fall from source to outlet and have made for themselves moderately deep valleys, the beds of which are filled with large boulders; the water attains a high velocity in the spring and winter freshets, a characteristic common to all streams on the eastern slope of the Blue Ridge.

The Perkiomen falls, from its source to the gauging-stations, about 800 feet in 24 miles; the Neshaminy, about 600 feet in 27 miles, and the Tohickon about 600 feet in 28 miles.

The gauging-station on the Perkiomen is above the East Branch. The watershed area includes the West Branch, the Upper Perkiomen and the West and East Swamp Creeks. The watershed above the gauging-station is about one-third of the total area drained by the stream.

The Neshaminy gauging-station is situated a short distance below the junction of the Big and Little Neshaminy, and the watershed above the gauging-station is about one-half the total area drained by the stream.

The Tohickon gauging-station is situated about one-eighth of a mile above its junction with the Delaware, the watershed above the gauging-station being nearly all the total area drained by the stream.

The surface of the ground is mostly farm land under a high degree of cultivation. The original forest growth has been almost entirely cut away and the little remaining timber is found generally on the banks of the creeks where the hillside is too steep to be cultivated, or on a few patches of bottom-land. This growth is mostly composed of hickory, chestnut, oak and ash; even this is fast disappearing to supply the ever-increasing demand for railroad-ties, fence-posts and rails. The proportion of cultivated land, woodland, etc., is as follows: woodland, about 20 per cent.; cultivated land, about 77.5 per cent.; roads, 2 per cent., and flats 0.5 per cent.

Under such surface-conditions the streams are subject to very sudden freshets. During heavy rains large quantities of surface soil are swept into the tributaries and are carried along with the rapidly moving torrent into the streams and rivers, to find a lodgment in the harbors and bays on the seaboard.

Observations on the amount of water passing off from such a watershed, to be of any value, must be carried on for a number of years. The data also show that the *average* rainfall, or the *average* flow is of little value in determining the amount of water that can be depended upon as a source of water-supply or water-power.

There can be no doubt that the average rainfall in the Eastern part of the United States is the same as it was two hundred years ago.

There is a changed condition of stream-flow due to the destruction of the forests which protected the surface of the ground, retarded evaporation and held back the surface water for a longer period of time.

The frozen ground in the winter months is without even nature's cold covering of snow to protect it, for the snow is blown by the uninterrupted force of the wind into great drifts, in the valleys and on the hillsides, there to remain until the first warm rain, when it adds its melted volume to that already passing off from the impervious ground, filling every valley and water-course to overflowing with a surplus of water. This condition lasts but a short time, and is followed by one exactly the reverse. The exposure of the surface soil in summer to the full power of the sun's rays bakes and hardens it, evaporation is greatest, surface soil yields up its moisture, ground-water falls lower and lower, the springs dry up, and the stream is reduced to almost nothing, only a little rivulet flowing among boulders.

The instruments used at the present time for collecting the data are twenty-two ordinary or field rain-gauges; three automatic rain-gauges, and three automatic stream-gauges.

The duties of the observer collecting rainfall-data consist in recording the beginning and ending of the rain, or snow reduced to rain, and the amount that has fallen each day at 8 P.M.

Printed blanks and pasteboard scales, one for each observation,

are furnished by the Bureau. These are filled up and returned at the end of the month.

The duties of the observer in charge of the automatic stream-gauge are to visit the gauge at least three times during the twenty-four hours, read the height of water on the gauge-board, recording the observation, with the hour of the day, on the automatic gauge roll.

In the winter a lamp must be kept burning in the float-box to prevent the water from freezing.

The instrument operates in the following manner: On the surface of the water an air-tight copper cylinder is floated, to which is attached a fine copper wire, passing over a pulley one foot in circumference. This turns a screw with a pitch of one thread per inch. This moves the pencil point backward or forward as the water rises or falls. The paper roll on which the pencil traces a line, is placed upon a roller in the instrument, attached to an eight-day clock, which is used to unwind and re-roll the paper. Small weights are attached to the rolls to keep a slight tension on the paper.

The instrument records the height of water automatically on the paper, in a continuous line. These rolls can be removed from the instrument at any time, but are generally run from one to two months.

The amount of water flowing in the stream is computed for each day, from this irregular line traced by the pencil.

The method of obtaining the curve showing the volume of stream-flow in cubic feet per second was by the use of a Francis weir for the low flows, and a current-meter for the larger ones. The volume of flow in cubic feet per second, found either by weir or meter, was plotted upon a sheet of paper, making the cubic feet per second the abscissas, and the heights of water the ordinates of the curve. A large number of observations was taken in this way for each stream, and the curve was drawn approximately through these points.

The highest flood-flows are obtained by projecting the curve beyond the points in the same general direction.

It is impossible to meter the stream at times of high water. The rise is generally very rapid to the highest point, and the fall

equally as fast. The high water of February 6, 1896, as plotted upon the diagram, shows this very plainly.

The stream-flow is computed in cubic feet per second, and tabulated in cubic feet per month, cubic feet per day and gallons per day. All of these tables are published in the Annual Report of the Bureau of Water each year.

As rainfall is usually expressed in inches, depth of water on the surface of the ground, for convenience of expression and comparison with the rainfall, the volume of stream-flow is also computed in inches depth of water on the watershed. The differences between inches of rainfall and inches of stream-flow show the amount taken away by other causes. The stream-flow in the diagram is shown in inches per month for fourteen years. The table shows the average inches of rainfall per month, also the maximum and minimum flow for each month.

The forces governing rainfall and stream-flow are gravitation and evaporation; evaporation acting continuously to raise the moisture above the earth's surface, and gravitation acting continuously to bring it back, either in the form of rain, snow or dew. Only a portion of the water falling upon the surface of the ground is found flowing in the streams; a portion is taken up by plant life; a portion runs directly into the streams; a portion sinks into or is absorbed and held by the ground, as a sponge holds water, forming a great reservoir, from which the water drains out slowly.

It is from this source that the springs and brooks are supplied and the stream-flow maintained. Rainfall and stream-flow follow each other in natural order, the amount and the rapidity of the rainfall, its distribution throughout the year, the geological and surface conditions, and the area of the watershed govern the volume of the stream-flow and produce either a maximum flow of freshets, or a minimum flow of low water.

We have but a faint idea of the immensity of these forces. For instance, we speak of one inch of rainfall, an amount which has often fallen in twenty minutes, on the 130 square miles comprising the area of the City of Philadelphia, as though it were a little thing; yet all the combined pumping power of 7 turbine water wheels and 30 steam engines which comprise the pumping plant

of the city, if worked continuously for one year, could not equal the force exerted by this one inch of rain, falling from an assumed height of 6,000 feet.

In computing the available stream-flow from a given watershed, for a given draft of water, it is essential to ascertain by rainfall records of the past the longest periods of least rainfall which have occurred in former years and which may occur again and which may occur in succession. Data of this kind are not often available; little reliance can be placed upon the results of one or two years' observations, but they are valuable for computation and comparison with longer observations on similar watersheds. There is a great difference in the annual rainfall, and a still greater comparative difference in the annual flow of streams.*

There is a vast difference in the spring and summer daily flow of these streams. The months of January, February and March are usually months of large stream-flow, while the months of August, September and October are months of least flow. The difference seems almost incredible. The maximum observed flow for one day was in September, 1888, in round numbers, 22,500,000 gallons per day per square mile of watershed; the minimum observed flow for one day was in September, 1885, and was only 21,700 gallons per day per square mile.

The average flow of the Perkiomen, per square mile, per day, for the past thirteen years, has been 1,160,000 gallons; of the Neshaminy, 1,130,000; of the Tohickon, 1,400,000; of the Sudbury, 1,050,000; of the Croton, 1,100,000.† It has been asserted

* The average rainfall for the past thirteen years at the 22 stations where observations are made for the Bureau, is about 48.5 inches. The excess in rainfall of the years 1888–1889 and 1890, the less number of years in which observations have been taken makes this average more than that of the Pennsylvania Hospital or the U. S. Weather Bureau. Of this average rainfall nearly 50 per cent., or 24.1 inches, are found flowing in the stream.

The average flows per year, per month, or per day, as before asserted, are of little value in determining the quantity of available stream flow.

† The average daily flow of the Perkiomen is found to be 177,900,000 gallons per day; of the Neshaminy, 157,600,000 gallons; of the Tohickon, 145,800,000. The maximum flow of the Perkiomen has been 5,305 cubic feet per second, or 3,433,000,000 per day, about equal to 18 days' pumpage of all the Water Bureau's plant; and the minimum flow as low as 3,800,000 gallons per day, or about 25 minutes' pumpage. The Neshaminy has been observed as high as 3,700,000,000 gallons per day, and as low as 2,800,000 gallons per day. The Tohickon has been observed as high as 3,600,000,000 gallons per day and as low as 130,000 gallons per day, or about one minute's pumpage of the Water Bureau.

that a draft of 1,000,000 gallons per day per square mile of watershed could be made upon Pennsylvania streams. One of the various schemes for supplying the city with water was based upon a draft of 920,000 gallons per day per square mile of watershed. The diagram is computed upon this amount of draft and shows the amount of storage per square mile of watershed required to prevent a failure in times of drought, the beginning of the draft upon the storage, the length of time the reservoirs would have been below the overflow line, and the time the reservoirs would again be full.

In the diagram it is to be remembered that the evaporation from the water surface is not included, as no large water surfaces are found on these streams, and this correction will still further increase the length of time of draft upon the storage.

It is also to be remembered that in computing for a water-supply the months of least flow are the months of greatest draft.

The Philadelphia water records show that the percentage of average consumption per month is as follows: January, 87; February, 81; March, 89; April, 89; May, 100; June, 108; July, 116; August, 116; September, 110; October, 108; November, 100; December, 96.

In constructing the diagram these percentages have been used.

The diagram shows plainly that a draft of 920,000 gallons per day per square mile of watershed would not be *safe* or even practicable.

The danger is still further increased by seepage, which cannot be prevented, and experience shows that contractors do not always build reservoir dams tight enough to hold water, and the flow by the dam cannot always be controlled.

The diagram also shows that the storage capacity for streams similar to the Perkiomen and Neshaminy must not be less than 200,000,000 gallons per square mile in order to prevent a deficiency in seasons of drought. This would require a storage capacity of about 144 reservoirs of the size of Queen Lane.

From observations on the Sudbury River, Mr. F. P. Stearns, Engineer of the Boston Metropolitan Board of Water Supply, in his annual report to the State Board of Health for 1890, states the following facts:

"Taking everything into account it may be said that the

greatest amount which can be made practically available from a square mile of watershed does not exceed 900,000 gallons per day, and the cases are very rare in which more than 600,000 gallons per day per square mile can be made available when it is necessary to store the water in artificial reservoirs."

The same report shows by a diagram that a draft of 900,000 gallons per day per square mile would keep the storage below the flow line for periods of eight years at a time.

Our own observations agree closely with these facts, difference of latitude and geological formation making some slight difference.

The diagram of storage, with a draft of 920,000 gallons per day per square mile, shows that the Perkiomen and Neshaminy creeks would have been below the overflow line from April, 1890, to April, 1895, a period of five years. The condition of the storage at the present time indicates a greater draft upon the storage than has ever occurred, since observations were begun fourteen years ago; the flow of the Perkiomen showing that it would require a storage of over 200,000,000 gallons on the Neshaminy, a storage of over 250,000,000 gallons per square mile. To prevent failure in 1896, this condition is continued into 1897 and seems to point to a still longer period before the storage will again be full. Although our observations do not extend over so long a period of time as those on the Sudbury, there is sufficient data to prove the assertion that a greater draft than 600,000 gallons per day per square mile, based upon artificial storage, can not be depended upon with safety.

The Schuylkill River, with a watershed of 1,800 square miles above Norristown, could be depended upon for a supply of 1,000,000,000 gallons per day, with an artificial storage of probably not more than 100,000,000 gallons per square mile of watershed.

With the natural facilities and advantages afforded for building storage dams, this volume of water could be safely and cheaply stored. The Schuylkill, without any further storage than is now found upon it, will furnish a supply of at least 225,000,000 gallons per day. The Delaware, above the Water Gap, with a watershed of about 4,000 square miles, will furnish about two and-a-half times more in volume than the Schuylkill and a larger daily draft can be depended upon without constructing storage dams.

INCHES OF RAINFALL FLOWING IN THE PERKIOMEN, NESHAMINY AND TOHICKON CREEKS.

WATERSHEDS.		AREA. Miles.	PERCENTAGE OF TOTAL AREA. Woodland.	Cultivated.	Flats.	Roads.	AVERAGE FOR 13 YEARS, 1883–1896. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	ANNUAL.
Perkiomen at Frederick		152.0	25	71	2	2	3.12	3.67	3.88	2.25	1.16	0.92	1.39	1.03	1.06	0.96	1.71	1.99	23 79
Neshaminy below Forks		139.3	6	92	½	2	3.58	4.20	3.82	2.10	1.02	0.69	0.99	0.88	0.94	0.75	1.53	2.17	23.03
Tohickon		102.2	24	72	2	2	4.17	4.93	4.77	2.61	2.04	0.90	1.37	1.27	1.37	0.95	2.12	2.50	28.98
Perkiomen at Frederick	Maximum						5.40	9.73	5.58	3.48	6.66	2.65	4.89	2.48	3.68	2.36	6.67	3.77	
	Minimum						0.59	1.25	2.38	0.97	0.46	0.28	0.17	0.28	0.16	0.20	0.34	0.91	
Neshaminy below Forks	Maximum						6.77	10.44	5.55	3 57	7.41	1.67	5.47	3.37	3.51	2.55	6.31	4.56	
	Minimum						1.60	0.90	1.84	1.03	0.35	0.08	0.04	0.14	0.03	0.06	0.11	0.41	
Tohickon	Maximum						7.34	10.41	6.37	4.76	8.58	3.43	6.41	3.75	5.49	3.54	7.97	4.28	
	Minimum						0.54	1.19	2.98	0.73	0.30	0.08	0.11	0.10	0.04	0 05	0.14	0.67	

PERKIOMEN, 1883–1884.

MONTHS.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	5.27	1.42	3.85		73.6	790,000
November	1.93	0.91	1.02		48.3	520,000
December	4.00	1.04	2.96		54.4	584,000
January	5.14	5.40	......		280.7	3,016,000
February	5.04	9.73	......		540.0	5,800,000
March	5.04	5.29	......		274.4	2,947,000
April	2.63	2.37	0.26		127.4	1,550,000
May	3.40	1.36	2.04		74.8	801,000
June	4.65	1.26	3.39		66.6	726,000
July	7.44	2.16	5.28		113.5	1,219,000
August	3.44	0.65	2.79		33.7	362,000
September	0.59	0.31	0.28		17.7	190,000
	48.57	31.90	21.87			
1884–1885.						
October	3.69	0.37	3.32		20.1	216,000
November	3.26	0.91	2.35		49.4	530,000
December	6.08	3.77	2.31		194.6	2,090,000
January	3.76	3.27	0.49		171.0	1,826,000
February	4.41	2.16	2.25		124.3	1,332,000
March	1.32	2.52	......		131.1	1,405,000
April	2.41	2.75	......		147.9	1,093,000
May	2.49	0.82	1.67		56.3	603,000
June	1.48	0.28	1.20		14.8	159,000
July	2.18	0.17	2.01		9.0	96,000
August	6.17	1.23	4.94		64.5	691,000
September	0.87	0.16	0.71		8.6	96,000
	38.12	18.41	21.25			

NESHAMINY, 1883–1884.

MONTHS.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	3.80	0.48	3.32		25.9	279,000
November	1.43	0.35	1.08		19.8	213,000
December	3.06	0.85	2.21		46.0	496,000
January	5.58	6.77	......		365.3	3,936,000
February	6.27	10.45	......		602.0	6,484,000
March	5.20	5.55	......		299.6	3,227,000
April	2.42	1.64	0.78		91.9	989,000
May	3.24	0.35	2.89		19.1	206,000
June	5.24	0.82	4.42		45.6	492,000
July	4.89	0.52	4.37		27.8	300,000
August	3.58	0.51	3.07		27.4	296,000
September	0.31	0.06	0.25		2.5	27,000
	45.02	28.35	22.39			
1884–1885.						
October	3.05	0.06	2.99		2.4	26,000
November	3.69	0.33	3.36		17.6	189,000
December	5.70	4.56	1.14		238.5	2,569,000
January	3.76	3.50	0.26		170.5	1,836,000
February	4.93	5.18	......		263.0	2,833,000
March	1.04	1.84	......		90.5	976,000
April	2.26	2.21	0.05		76.4	824,000
May	2.44	0.56	1.88		28.9	312,000
June	1.68	0.08	1.60		4.2	45,100
July	2.19	0.04	2.15		2.6	28,000
August	6.38	0.96	5.42		50.0	539,000
September	1.16	0.03	1.13		1.7	18,100
	38.28	19.35	19.98			

TOHICKON, 1883–1884.

MONTHS.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	4.40	0.88	3.52		45.6	495,000
November	1.64	0.57	1.07		30.9	333,000
December	4.04	0.97	3.07		50.2	540,000
January	5.32	7.34	......		381.7	4,112,000
February	5.45	10.41	......		577.7	6,223,000
March	5.19	6.02	......		313.3	3,371,000
April	2.52	1.89	0.63		101.9	1,098,000
May	3.54	0.64	2.90		33.2	357,000
June	6.48	3.43	3.05		183.3	1,971,000
July	7.05	2.82	4.23		141.2	1,522,000
August	3.99	0.28	3.71		14.4	155,000
September	0.46	0.07	0.39		3.9	41,400
	50.08	35.32	22.57			
1884–1885.						
October	4.00	0.12	3.88		6.8	73,700
November	3.51	1.16	2.35		62.9	677,000
December	6.26	3.94	2.32		205.9	2,218,000
January	4.35	4.48	......		233.9	2,520,000
February	4.83	3.57	1.26		198.2	2,136,000
March	1.57	2.98	......		154.8	1,668,000
April	2.69	3.98	......		213.9	2,304,000
May	2.16	0.50	1.66		25.7	277,000
June	0.84	0.08	0.76		3.9	42,000
July	2.30	0.23	2.07		11.4	123,000
August	8.17	1.23	6.94		65.6	706,000
September	0.53	0.04	0.49		1.9	21,200
	41.21	22.31	21.73			

PERKIOMEN, 1885–1886.

Months.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	4.74	0.43	4 31		22.2	240,000
November	3.88	1.79	2.09		94.7	1,020,000
December	3.18	2.45	0.73		126.5	1,362,000
January	4.21	3.03	1.18		158.1	1,702,000
February	5.08	5 64	......		323.1	3,480,000
March	3 96	2.56	1.38		132.6	1,428,000
April	3.00	3.42	.....		182.5	1,965,000
May	6.60	2.64	3.96		135.4	1,458,000
June	5.26	1.89	3.37		100.9	1,086,000
July	5.06	1.11	3.95		57.3	617,000
August	1.44	0.35	1.09		17.7	189,000
September	1.37	0.23	1.14		12.4	133,000
	47.78	25.56	23.20			
1886–1887.						
October	2.35	0.26	2.09		13.0	140,000
November	5.28	1.53	3.75		82.9	900,000
December	3.76	1.43	2.33		74.9	807,000
January	4.55	4.00	0.55		206.6	2,225,000
February	5.64	4.23	1.41		242.9	2,616,000
March	2.99	3.03	......		156.8	1,690,000
April	2.84	1.25	1.59		67.4	726,000
May	1.85	0.72	1.13		37.9	408,000
June	5.87	0.76	5.11		40.7	439,000
July	8.63	2.07	6 56		107.6	1,159,000
August	2.76	1.43	1.33		74.5	801,000
September	3.64	0.62	3.02		32.6	351,000
	50.16	21.33	28.87			

NESHAMINY, 1885–1886.

Months.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	5.56	0.17	5.39		9.0	96,700
November	4.50	1.53	2.97		79.6	860,000
December	2 88	1.73	1.15		86.0	927,000
January	5.11	5.21	......		262.3	2,826,000
February	6.18	6.55	......		263.2	3,912,000
March	3.72	2.30	1.42		114.7	1,235,000
April	2.93	3.57	......		185.7	2,001,000
May	5.79	2 09	3.70		104.8	1,130,000
June	5.67	0.91	4.76		47.3	509,000
July	5.40	0.81	4.59		39.6	434,000
August	1.60	0.15	1.45		7.9	79,000
September	0.91	0.05	0.86		2.2	23,000
	50.25	25 07	26.29			
1886–1887.						
October	2.77	0.06	2 71		2.6	28,000
November	3.92	0.55	3.37		28.7	310,000
December	3.30	2 34	0.96		117.1	1,261,000
January	4.63	4.22	0.41		211.0	2,273,000
February	5.05	3.94	1 11		218.2	2,350,000
March	3.58	3.25	0.33		163.6	1,761,000
April	3.17	1.46	1.71		75.9	817,000
May	2.15	0 71	1.44		35.2	378,000
June	7.27	1.67	5 60		85.8	925,000
July	8.15	1.96	6 19		97.3	1,047,000
August	3.84	0.81	3.03		40 2	432,000
September	4 06	0 41	3.65		21.8	236,000
	51.89	21.38	30.51			

TOHICKON, 1885–1886.

Months.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	4.80	0.33	4.47		18.1	195,000
November	4.67	2 57	2.10		138.5	1,492,000
December	3.06	1.77	1.29		93 0	1,002,000
January	4.15	4.36	......		22.8	2,452,000
February	6.01	9.19	......		534.4	5,756,000
March	4.76	4.28	0.48		224.5	2,424,000
April	3.42	4.76	......		257.2	2,770,000
May	7.14	3.43	3.71		178.4	1,921,000
June	4.53	1.40	3.13		75.8	816,000
July	5.48	0.77	4.71		40.4	435,000
August	1.09	0.10	0.99		5 3	57,000
September	1.30	0.03	1 27		1.5	158,000
	50.41	32.99	22.15			
1886–1887.						
October	2.59	0.05	2.54		2.3	25,000
November	5.16	1.96	3.20		105.6	1,138,000
December	3.83	2.38	1.45		124.4	1,340,000
January	4.24	5.04	......		263.8	2,847,000
February	5.47	5.25	0.22		303.4	3,268,000
March	3.06	3.83	......		200.5	2,160,000
April	2.41	1.01	1.40		54.5	588,000
May	2.59	0.93	1.66		49.2	531,000
June	5.77	1.21	4.56		64.6	697,000
July	8.13	1.63	6.50		85.3	920,000
August	5.29	1.96	3.33		101.4	1,094,000
September	3.36	0 40	2.96		22.3	241,000
	51.90	25.65	27.82			

MONTHS.	PERKIOMEN, 1887–1888. Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.	NESHAMINY, 1887–1888. Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.	TOHICKON, 1887–1888. Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	1.45	0.43	1.02		22.7	245,000	1.90	0.36	1.54		18.0	194,000	1.93	0.25	1.68		13.3	142,000
November	1.61	0.40	1.21		21.4	231,000	1.63	0.26	1.37		13.6	147,000	1.42	0.26	1.16		14.0	151,000
December	6.65	2.13	4.52		109.3	1,177,000	6.13	2.88	3.25		143.9	1,550,000	6.53	3.20	3.33		166.3	1,790,000
January	5.01	3.66	1.35		188.8	2,036,000	4.47	4.60	......		240.0	2,585,000	5.31	6.38	......		335.4	3,612,000
February	4.08	4.41	......		244.8	2,641,000	3.98	5.49	......		305.4	3,290,000	4.34	6.72	......		373.9	4,030,000
March	5.15	5.10	0.05		266.6	2,876,000	5.15	4.89	0.26		254.9	2,750,000	5.23	6.27	......		324.7	3,522,000
April	3.43	3.45	......		185.6	2,001,000	3.88	2.79	0.09		150.8	1,627,000	4.08	4.28			230.6	2,470,000
May	3.16	0.92	2.24		48.0	517,000	2.87	0.52	2.35		27.5	300,000	3.03	0.52	2.51		27.1	292,000
June	1.62	0.39	1.23		20.8	224,000	2.34	0.22	2.12		10.8	116,000	1.69	0.15	0.54		8.8	96,000
July	2.77	0.25	2.52		13.0	141,000	3.71	0.15	3.56		7.9	85,000	3.20	0.06	3.14		4.2	43,000
August	8.03	1.53	6.50		79.4	856,000	5.78	0.64	5.14		34.6	372,000	8.07	1.78	6.29		92.0	991,000
September	7.35	3.68	3.67		197.4	2,128,000	6.93	2.63	4.30		140.9	1,518,000	8.32	5.49	2.83		293.2	3,168,000
	50.31	26.35	24.31				48.78	25.43	23.98				53.15	35.36	21.48			
	1888–1889.						1888–1889.						1888–1889.					
October	3.41	1.26	2.15		64.9	702,000	3.76	1.05	2.71		55.4	600,000	4.06	1.54	2.52		81.0	873,000
November	3.42	2.46	0.96		133.2	1,438,000	3.49	2.34	1.15		128.9	1,389,000	3.66	3.11	0.55		162.2	1,745,000
December	4.37	2.88	1.49		148.7	1,608,000	3.72	3.16	0.56		163.8	1,765,000	4.35	3.48	0.87		182.2	1,966,000
January	3.86	3.27	0.59		171.2	1,851,000	3.61	2.92	0.69		153.2	1,651,000	4.43	4.38	0.05		228.3	2,440,000
February	1.99	1.47	0.52		84.9	918,000	1.90	0.90	1.00		89.7	967,000	2.37	1.52	0.85		87.7	946,000
March	3.17	3.01	0.16		155.2	1,678,000	3.37	2.90	0.47		149.7	1,613,000	3.67	3.86	......		200.0	2,160,000
April	5.05	2.07	2.98		111.8	1,209,000	4.83	2.07	2.76		110.6	1,192,000	4.90	2.88	2.02		155.0	1,673,000
May	4.55	1.58	2.97		82.2	885,000	4.89	1.49	3.40		92.2	993,000	5.41	1.70	3.71		88.7	957,000
June	7.16	2.65	4.51		142.6	1,536,000	5.25	1.16	4.09		62.5	673,000	6.94	2.29	4.65		111.1	1,200,000
July	12.23	4.89	7.34		252.5	2,786,000	12.42	5.47	6.95		283.5	3,051,000	12.33	6.41	5.92		334.5	3,611,000
August	3.99	2.48	1.51		128.7	1,386,000	4.75	3.37	1.28		176.6	1,900,000	4.63	3.75	0.88		196.0	2,108,000
September	7.00	2.80	4.20		151.0	1,636,000	8.56	3.51	5.05		190.6	2,054,000	7.91	3.40	4.51		186.0	2,007,000
	60.20	30.82	29.38				60.55	30.34	30.21				64.66	38.32	26.53			

PERKIOMEN, 1889-1890.

MONTHS.	Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October.......	4 780	2.342	2.41		122.9	702,000
November...	8.665	6.670	1.99		363.2	1,438,000
December....	1.700	1.275	0.43		117.8	1,608,000
January......	2.810	2 051	0.76		106.9	1,151,000
February....	4 370	3.583	0.79		206.8	2,229,000
March........	6.565	5.580	0.98		329.5	3,123 000
April..........	2.795	2.509	0 28		140.2	1,511,000
May..	6.430	3.151	3.28		165.7	1,785,000
June.........	2.400	0.936	1.40		50.2	541,000
July..........	5.195	1.091	4 10		56.1	604,000
August.......	6.750	1.080	5.67		57 4	618,000
September...	3 710	1 299	2.41		70.4	752,000
	56.170	31.567	24.59			
1890-1891.						
October.......	5.48	2.35	3.13		122.	1,314,000
November...	1.12	0.87	0 25		47.0	507,000
December....	2.71	1.14	1.57		58.3	633,000
January......	6.30	5.29	1.01		275.9	2,971,000
February....	3.84	4 18	0.34		241.9	2,605,000
March........	6.07	4.29	1.78		242 6	2,614,000
April..........	1.98	1.80	0.18		97.3	1,048,000
May..........	1.99	0.65	1 34		34.6	372,000
June.........	3.02	0.36	2.66		19.4	209,000
July..........	7.73	0.85	6.88		43.7	471,000
August.......	7.57	2.04	5.53		106.7	1,150,000
September..	2.63	1.53	1.10		82.5	889,000
	50.44	25.35	25.09			

NESHAMINY, 1889-1890.

MONTHS.	Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October.......	5.09	2.55	2.54		130.8	1,410.000
November...	8.53	6.31	2.22		337.4	3,635,000
December....	1.88	1.88	......		98.2	1,057,000
January......	2.88	1.60	1 28		83.9	905,000
February....	4 28	3.00	1.28		171.1	1,842,000
March........	5.36	5.09	0.27		267.1	2,880,000
April..........	2.46	1.77	0.69		95.5	1,030,000
May..	5.20	1.51	3.69		78.0	841,000
June.........	4.51	0 99	3.52		57.1	616 000
July..........	4.47	0.63	3.84		32.4	340,000
August.......	5 30	0.53	4.77		27.2	294,000
September...	2 99	0.39	2 60		16.6	180,000
	52 95	26.25	26.70			
1890-1891.						
October.......	6.18	2.16	4.02		112.8	1,215,000
November...	1.06	0.78	0.28		42.1	452,000
December....	2.86	1.37	1.49		70.9	764,000
January......	6.28	5.78	0.50		302.8	3,270,000
February....	4.61	4.47	0.14		258.5	2,791,000
March........	4.91	4 32	0.59		226.3	2,440,000
April..........	1.90	1.48	0.42		79.6	860,000
May..........	2.92	0.32	2.60		16.8	180,000
June.........	3.46	0.24	3.22		13.4	140,000
July..........	5.71	0.34	5 37		17.4	186,000
August.......	6.73	1.95	4.78		101.4	1,086,000
September..	2.54	1.27	1.27		66.0	730,000
	49.16	24.48	24.68			

TOHICKON, 1889-1890.

MONTHS.	Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October.......	4.57	2.33	2 24		121.6	1,311,000
November...	8.86	7.97	0.89		430.4	4,636,000
December....	1.99	1.92	0.07		100.9	1,090,000
January......	2.82	2.06	0.76		106.4	1.148,000
February....	4.73	3.78	0.95		217.8	2,350,000
March........	6.77	6.37	0.40		353.3	3.812,000
April..........	2.48	1.79	0.69		95.6	1,032,000
May..	6.30	3.09	3.21		158.5	1,710,000
June.........	3 93	0 75	3.18		40.4	434,000
July..........	5.81	0.87	4 94		46.1	498,000
August.......	5.75	0.92	4.83		47.3	510 000
September...	2.98	1.22	1.76		65.7	709,000
	56.99	33.07	23.92			
1890-1891.						
October.......	6.21	3.54	2.67		187.9	2,025,000
November...	1.01	0.69	0.32		36.8	398,000
December....	2.75	1.51	1.24		79.3	858,000
January......	6.15	6.15	......		319.4	3,447,000
February....	4.58	5.68	1.10		318.0	3,431,000
March........	4.79	5.03	0.24		261.7	2,824,000
April..........	1.97	1.58	0.39		84.5	911,000
May..........	2.83	0.28	2.55		14.5	157,000
June.........	3.38	0.17	3.21		10.2	109,000
July..........	7.49	0.90	6.59		47.7	515,000
August.......	8.90	3.92	4.98		205.1	2,214,000
September..	1.37	0.94	0.43		49.8	538,000
	51.43	30.39	22.38			

MONTHS.	PERKIOMEN, 1891-1892.						NESHAMINY, 1891-1892.						TOHICKON, 1891-1892.					
	Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS.					Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS.					Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS.				
		Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.		Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.		Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October........	3.53	0.56	2.97		29.0	313,000	3.66	0.55	3.11		27.9	300,000	3.81	0.46	3.35		22.9	247,000
November....	1.99	0.60	1.39		31.4	340,000	1.88	0.56	1.32		31.0	335,000	1.98	0.63	1.35		33.9	366,000
December.....	4.73	2.89	1.84		149.6	1,611,000	4.19	3.02	1.17		157.4	1,696,000	5.09	4.28	0.81		222.5	2,400,000
January.......	5.56	4.79	0.77		250.1	2,694,000	5.09	5.14	0.05		273.3	2,860,000	5.49	6.53	1.04		340.2	3,668,000
February......	1.25	1.17	0.08		63.2	681,000	1.07	0.97	0.10		53.6	570,000	1.22	1.19	0.03		66.1	711,000
March.........	4.99	4.05	0.94		211.6	2,280,000	4.13	3.56	0.57		185.9	1,990,000	4.13	4.87	0.74		254.2	2,743,000
April..........	1.79	1.16	0.63		62.4	672,000	2.24	1.03	1.21		54.0	580,000	1.95	0.84	1.11		45.1	486,000
May............	5.32	1.83	3.49		95.0	1,023,000	5.83	1.29	4.54		82.9	890,000	5.55	2.05	3.50		110.5	1,192,000
June...........	3.18	0.89	2.29		49.2	530,000	3.38	0.58	2.80		30.4	330,000	3.20	0.70	2.50		38.3	413,000
July...........	5.19	0.73	4.46		39.7	428,000	4.83	0.53	4.30		28.5	306,000	4.26	0.51	3.75		26.3	284,000
August.........	2.69	0.76	1.93		39.4	424,000	3.37	0.20	3.17		10.3	111,000	3.76	0.31	3.45		17.0	183,000
September....	2.21	0.33	1.88		17.3	190,000	2.59	0.11	2.48		5.8	61,000	2.91	0.19	2.72		14.2	151,000
	42.43	19.76	22.67				42.26	17.54	24.72				43.34	22.56	20.79			
	1892-93.						1892-1893.						1892-1893.					
October......	0.48	0.20	0.28		10.8	115,000	.40	0.04	0.36		21.6	23,300	0.64	0.09	0.55		4.92	53,000
November....	6.64	2.13	4.51		113.6	1,218,000	7.14	1.79	5.35		94.6	1,008,000	7.10	3.19	3.91		171.4	1,842,000
December,....	1.88	1.22	0.66		61.4	690,000	1.69	1.15	0.54		60.0	646,000	1.58	1.67	0.09		87.1	937,000
January.......	2.38	1.45	0.93		75.7	816,000	3.13	2.00	1.13		104.2	1,123,000	2.96	2.21	0.75		115.9	1,250,000
February.....	5.53	4.04	1.49		232.9	2,508,000	5.68	4.89	0.79		284.7	3,066,000	5.88	6.64	0.76		384.7	4,154,000
March........	2.96	4.93	2.03		256.2	2,767,000	2.66	4.66	......		243.2	2,620,000	2.46	4.53	2.07		236.0	2,543,000
April.........	4.11	2.30	1.81		125.0	1,343,000	4.97	2.88	2.09		156.2	1,682,000	4.96	3.22	1.74		172.0	1,853,000
May...........	5.36	3.27	2.09		167.8	1,821,000	4.03	2.94	1.09		150.4	1,663,000	4.98	3.78	1.20		195.7	2,108,000
June...........	3.75	0.56	3.19		29.8	321,000	3.20	0.45	2.75		24.0	260,000	4.05	0.44	3.61		23.5	253,000
July...........	2.00	0.300	1.70		15.1	166,000	1.60	0.13	1.47		6.9	74,000	2.10	0.10	2.00		5.5	60,000
August......	6.45	0.96	5.49		50.8	546,000	7.41	1.12	6.29		57.0	614,000	8.67	1.56	7.11		81.3	878,000
September....	3.14	0.60	2.54		33.2	357,000	3.36	0.57	2.79		30.8	332,000	3.20	0.83	2.37		44.5	480,000
	44.61	21.96	22.66				45.27	22.61	24.65				48.58	28.26	20.32			

PERKIOMEN, 1893–1894.

MONTHS.	Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October........	2.82	0.89	1.93		45.5	485,000
November.....	4.22	1.84	2.38		98.9	1,064,000
December.....	2.75	1.90	0.85		94.8	1,026,000
January.......	1.78	0.70	1.08		36.5	393,000
February......	4.22	2.42	1.80		140.2	1,510,000
March.........	1.45	2.38			124.2	1,336,000
April	2.54	1.71	0.83		92.1	992,000
May	11.63	6.66	4.97		346.8	3,735,000
June...........	3.61	1.13	2.48		60.7	653,000
July............	2.93	0.58	2.35		30.5	328,000
August.........	2.23	0.34	1.89		17.7	190,000
September....	6.36	1.67	4.69		93.1	1,002,000
	46.54	22.22	25.25			
1894–1895.						
October........	6.24	1.66			86.4	936,000
November.....	2.80	1.85			99.6	1,073,000
December.....	4.81	2.83			147.5	1,589,000
January.......	4.30	3.06			159.4	1,717,000
February......	1.58	1.25			72.0	776,000
March	2.96	3.91			203.6	2,192,000
April	6.12	3.48			187.3	2,018,000
May............	3.45	0.98			51.0	549,300
June	3.56	0.43			23.2	250,100
July	3.96	0.61			31.8	342,600
August.........	3.36	0.28			14.5	155,600
September....	0.93	0.18			9.0	97,400
	44.07	20.52				

NESHAMINY, 1893–1894.

MONTHS.	Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October........	3.30	0.59	2.71		30.3	326,000
November.....	4.41	2.58	1.83		138.7	1,494,000
December.....	2.78	2.61	0.17		136.2	1,465,000
January.......	1.71	0.79	0.92		41.0	442,000
February......	4.05	2.68	1.37		154.2	1,665,000
March.........	1.61	2.67			139.1	1,498,000
April	3.04	2.00	1.04		107.5	1,160,000
May	13.49	7.41	6.08		385.6	4,154,000
June...........	2.55	1.05	1.50		61.4	662,000
July............	3.72	0.43	3.29		22.2	239,000
August.........	2.68	0.34	2.34		17.5	188,000
September....	8.18	2.27	5.91		122.2	1,317,000
	51.52	25.42	26.16			
1894–1895.						
October........	5.25	1.48			77.7	836,000
November.....	3.02	2.37			127.5	1,374,000
December.....	4.14	2.31			120.3	1,296,000
January.......	4.68	3.46			177.2	1,908,000
February......	1.12	1.77			102.2	1,101,000
March	3.17	4.26			221.8	2,389,000
April	5.32	3.34			179.4	1,932,000
May............	2.54	0.70			36.2	390,000
June	4.30	0.52			27.7	298,600
July	3.74	0.88			45.7	492,000
August.........	3.37	0.67			35.1	377,000
September....	0.74	0.05			2.9	30,800
	41.39	21.76				

TOHICKON, 1893–1894.

MONTHS.	Total Rainfall in Inches.	STREAM FLOW FROM GAUGINGS. Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October........	3.73	0.60	3.13		31.9	344,000
November.....	4.38	2.63	1.75		143.2	1,542,000
December.....	3.17	3.10	0.07		161.5	1,738,000
January.......	1.82	0.80	1.02		41.8	451,000
February......	3.96	3.80	0.16		219.0	2,360,000
March.........	1.65	3.09			161.3	1,738,000
April	2.91	2.28	0.63		122.7	1,322,000
May	13.53	8.58	4.95		446.4	4,808,000
June...........	2.63	0.53	2.10		28.9	311,000
July............	2.28	0.19	2.09		9.8	105,000
August.........	2.04	0.12	1.92		5.9	64,000
September....	9.44	3.34	6.10		179.4	1,933,000
	51.54	29.06	23.92			
1894–1895.						
October........	5.18	2.10			109.3	1,177,000
November.....	3.01	2.67			144.0	1,551,000
December.....	4.60	3.57			185.8	2,001,000
January.......	4.19	3.96			205.9	2,218,000
February......	0.96	1.70			98.1	1,055,000
March	3.11	5.37			279.5	3,011,000
April	5.50	4.65			250.3	2,695,000
May............	2.99	0.66			34.1	367,600
June	4.49	0.27			14.6	157,000
July	3.53	0.81			42.0	452,000
August.........	4.43	0.38			18.9	203,600
September....	0.67	0.05			1.9	21,300
	42.66					

PERKIOMEN, 1895-1896.

MONTHS.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	3.46	0 23	3.23		12.43	133,900
November	1.86	0.34	1.52		20.25	218,100
December	3.13	0.91	2.22		47.46	511,000
January	0.91	0.59	0.32		30.90	333,000
February	5 97	3.50	2.47		194.76	2,098,000
March	4.43	3.83	0.60		199.1	2,145,000
April	1.85	0.97	0.88		52.1	361,000
May	3.70	0.46	3.24		24.84	267,000
June	4.53	0.48	4.05		25.80	278,000
July	9.31	2.01	7.30		104.19	1,122,000
August	1.21	0.34	0.87		15.81	170,200
September	5 18	0.65	4.53		34.8	375,000
	45 54	14.31	31.23			
1896-1897.						
October	4.72	1.48	3.24		76.8	827,000
November	4.72	2.06	2.66		110.7	1,192,000
December	0.65	0.81			42.1	453,000
January	2 05	1.18			61.4	661,000
February	2.90	2.93			169.2	1,822,000

NESHAMINY, 1895-1896.

MONTHS.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average Loss for Years.	Cub. Ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	3 26	0.08	3.18		4.28	46,100
November	2.21	0.11	2.10		6.00	64,600
December	1.85	0.40	1.45		20.88	225,000
January	1.31	0 59	0 72		30.66	330,000
February	7.79	4.73	3.06		263.28	2,836,000
March	5.09	4.37	0.72		227.6	2,451,000
April	1.63	1 07	0.56		57.36	618,000
May	2 85	0.38	2.47		19.8	213,400
June	4.70	0.41	4.29		21.7	234,300
July	5.12	1.04	4.08		54.3	584,400
August	0 98	0 20	0.78		10.6	114,200
September	5.88	0 96	4.92		51.6	556,000
	42.67	14.34	28.33			
1896-1897.						
October	2.64	0.93	1.71		48.4	521,000
November	4 13	1.52	2.61		81.96	882,000
December	0.85	0.76	0.09		49.3	423.000
January	2.04	1.29			67.3	724,000
February	3.20	2.53			146.0	1,573,000

TOHICKON, 1895-1896.

MONTHS.	Total Rainfall in Inches.	Stream Flow from Gaugings: Inches flowing in Stream.	Loss or Evaporation.	Average loss for years.	Cub. ft. per Minute per Sq. Mile.	Gallons per 24 hours per Sq. Mile.
October	3.85	0.09	3.76		4.82	51,900
November	2.11	0.14	1.97		11.76	126,000
December	2.51	0.67	1.84		34.72	374,000
January	1.18	0 54	0.64		27.94	301,000
February	7.90	4.58	3.32		273.48	2,946,000
March	5.44	5 48			285.02	3,071,000
April	1.48	0.73	0.75		39.3	423,500
May	3.18	0.30	2.88		16.1	173,600
June	4.07	0.18	3.89		9.5	101,900
July	8.06	2.54	5.52		132.1	1,423,000
August	1.63	0.19	1.64		9.6	103,800
September	5.83	1.12	4.71		60.4	650,000
	47.24	16.56	30.68			
1896-1897.						
October	2.67	1.06	1.61		55.4	596,500
November	4.08	2.34	1.74		125.7	1.354,000
December	0.94	0.81	0.13		41.7	449,000
January	2.21	1.80			94.0	1,012,000
February	3 11	2.93			168.6	1,816,000

NOTES AND COMMUNICATIONS.

THE MISSISSIPPI RIVER.

At the meeting of April 3, 1897, Mr. John Birkinbine presented the following on this subject: With public attention drawn to the Mississippi river by reason of the high water in the main stream and its tributaries, causing immense areas to be overflowed, and widespread devastation to result, it may be of interest to summarize some features of the enormous drainage area of the "Father of Waters," an area extending from the crest of the Alleghenies to the crest of the Rocky Mountains, and from the Gulf of Mexico to beyond the Canadian border, omitting a narrow belt about the Great Lakes and the streams running into the South Atlantic and Gulf of Mexico.

All, or practically all, of fourteen States and two Territories are drained by the Mississippi or its tributaries, and portions of fourteen other States and one Territory also contribute to its flow, a total of twenty-eight States and three Territories.

A traveler starting westward from Philadelphia over our Pennsylvania Railroad, meets the drainage basin of the Mississippi river when he emerges from the tunnel bored through the crest of the mountain at Gallitzin and he would remain in the same basin in following a nearly due west course until after passing the cloud city of Leadville, Col., at an elevation of over 10,000 feet above sea level, this city being on the headwaters of the Arkansas river, which cuts through the Royal Gorge made famous by its picturesque characteristics.

If the journey took a more northwesterly course it might be continued beyond the Yellowstone Park and to Helena, Mont., or even into British America, without having been beyond the drainage basin of the Mississippi river. Bismarck, N. Dak.; Cheyenne, Wyo.; Denver, Col.; St. Paul, Minn.; Madison, Wis.; Springfield, Ill.; Indianapolis, Ind.; Columbus, O.; Charleston, W. Va.; Pittsburgh, Pa.; Chattanooga, Tenn.; Asheville, N. C., are all well within the watershed of the Mississippi river.

In an article in the *Engineering Magazine*, Mr. James L. Held Greenleaf gives the area of the Mississippi watershed as 1,259,000 square miles, which is 42 per cent. of the total area of the United States, exclusive of Alaska, twenty-eight times the area of the State of Pennsylvania, or twelve times the combined area of New York, Pennsylvania, New Jersey and Delaware. He gives the minimum flow of the river at 175,000 cubic feet per second, the average flow 664,000 cubic feet, and the maximum flow, which may possibly be exceeded in the present emergency, of 1,800,000 cubic feet per second. The flow per square mile in cubic feet per second being minimum 0.139, average 0.528, maximum 1.43. He divides the drainage basin according to the prominent tributaries as follows:

Mississippi above the mouth of the Missouri, 173,000 square miles, with a mean annual rainfall of 34.7 inches.

Missouri river, drainage 528,000 square miles, rainfall 19.6 inches.

Ohio river, drainage 214,000 square miles, rainfall 43.1 inches.

Arkansas river, drainage 161,000 square miles, rainfall 28.3 inches.

Red river, drainage 97,000 square miles, rainfall 38.3 inches.

Other tributaries, drainage 86,000 square miles, rainfall ranging from 41.3 to 53.3 inches.

He has also divided the rainfall into seasons and given the total flow and flow in cubic feet per second for each of the tributaries.

When the varied climatic conditions of this great area are taken into consideration, and the possibility of the nearly simultaneous melting of snows on the Alleghenies and Rocky Mountains, in the swamps of northern Minnesota, and upon the great stretch of prairie land, coupled with the heavy downpours which prevail in the lower region of the river in the springtime, one need not be surprised at the tremendous volume of water which such a combination of circumstances forces through the narrow outlet of this stream into the Gulf of Mexico.

When we remember that one inch of rain on a square mile, if it all flows off, represents a volume of 2,323,200 cubic feet, 17,377,536 gallons, or 72,600 net tons of water, and consider the immense surface of 1,259,000 square miles, imagination fails to grasp the magnitude of the quantities involved. Owing to the territory covered, it may be seldom that one inch of rain would simultaneously fall over this great area, and if such were the case it would not all reach the outlet, but for the purpose of indicating what those quantities are, a calculation has been made which shows that an inch of rain on the drainage basin of the Mississippi River is equivalent to 2,924,908,800,000 cubic feet, 21,878,317,824,000 gallons, or 91,403,400,000 net tons.

The boundaries of the eastern watershed range from 2,000 to 4,000 feet in height, the western boundary being much higher, especially in the central and northern portion, where it reaches from 8,000 to 14,000 feet. The southwestern and southeastern boundary being low, and the same may be said of the northern boundary, except at the head-waters of the main stream, which approximate 2,000 feet. The elevations of some of the important points along the main river and its branches are as follows, most of the heights being for low water, above mean sea level: Memphis, Tenn., 183; Cairo, Ill., 270; St. Louis, Mo., 380; Rock Island, Ill., 542; St. Paul, Minn., 683 feet. These are on the main stream. On the Ohio and its drainage, Cincinnati, O., 432; Columbus, O., 720; Pittsburgh, Pa., 699; Oil City, Pa., about 1,000; Asheville, N. C., 2,000; while on the Missouri River may be mentioned, Kansas City, Mo., 716; Omaha, Neb., 960; Bismarck, Dak., 1,618 feet.

The normal cross-sections of the Mississippi River are given as follows: At New Orleans, 480,000 feet; at Cairo, 325,000 feet; Junction of the Ohio, 260,000 feet; Junction of the Arkansas, 56,000 feet; Junction of the Red River, 52,000 feet.

BOOK REVIEWS.

THE ENTROPY TEMPERATURE-ANALYSIS OF STEAM-ENGINE EFFICIENCIES. By Sidney A. Reeve, M.E., Adjunct Professor of Steam Engineering at the Worcester Polytechnic Institute. Progressive Age Publishing Company, New York.

For this work, Prof. Reeve has prepared an interesting diagram for a more thorough analysis of heat-engine efficiencies than is usual in that class of investigation.

The diagram is similar to, but an improvement on, a diagram prepared by Prof. Boulvin, of Ghent, and illustrated in *Engineering* (London), January 3, 1896.

Credit is given to Willard Gibbs, of Yale, for original discovery in the application of the method. It is exceedingly difficult to define accurately all that is implied by the term entropy, nor do the founders of the science of thermodynamics entirely agree in its interpretation as applied to the complex system of heat-exchanges, which are continually occurring in the steam-engine. But, while we may not be able to clearly express what entropy is, in a physical sense, we may employ it mathematically as a working hypothesis, as consistently as the atomic theory is used in chemistry.

Prof. Reeve, by using a problem in hydraulics as an illustration, conveys very neatly an idea of the application of entropy in thermodynamics. This is a subject that none can afford to ignore, who desire to obtain accurate knowledge of the exchanges of heat in the steam-engine, and the diagram, prepared by Prof. Reeve, is of universal application to any accurate typical indicator diagram. It is sometimes asserted that steam-engineering, as an exact science, ranks below electrical engineering, as improvements in design are obtained too much by the "cut and try" method. Work, such as this, of Prof. Reeve, tends to remove the reproach, and should be welcomed as a substantial aid and an advance. J. C.

ABSTRACT OF MINUTES OF THE CLUB.

APRIL 3.—The President in the chair. Sixty-five members and visitors present.

Mr. Charles Jacobsen read a paper on "Experiments for Determining the Velocity of the Flow of Water."

The subject was discussed by Messrs. William Easby, Jr., John C. Trautwine, Jr., Allen J. Fuller, J. Kay Little, William H. Bixby, John E. Codman and L. Y. Schermerhorn.

Messrs. E. F. Smith and Allen J. Fuller presented discussions of the subject of "Construction of Queen-Lane Reservoir."

Mr. John Birkinbine presented data to summarize some features of the enormous drainage-area of the Mississippi River.

APRIL 17.—The First Vice-President in the chair. Sixty-six members and visitors present.

Mr. Charles F. Scott (non-member) gave an illustrated lecture on "The Installation of the Niagara Falls Power Company."

The subject was discussed by Coleman Sellers.

The Tellers reported the election of Messrs. Charles J. Dougherty and Percival Roberts, Jr., to active membership; Messrs. G. Howard Perkins, Jr., A. H. Holcombe, Edgar O. Macferran, and George B. Bains, 3d, to junior membership, and Mr. Luther S. Bent to associate membership.

MAY 1.—The President in the chair. Sixty-one members and visitors present.

The Secretary announced the receipt of an invitation from the Provost and Trustees of the University of Pennsylvania to the members of the Club to be present at the dedication of the Flower Astronomical Observatory.

A letter was read from Mr. F. H. Lewis, suggesting that the Club should consider the provisions of the new Building-Law before its final adoption by the Pennsylvania Legislature. The matter was informally discussed, and was referred to the Board of Directors.

Mr. Paul L. Wolfel read a paper on "The Superstructure of the Delaware-River Bridge at Philadelphia."

The subject was discussed by Messrs. James Christie, Edgar Marburg and Francis Schumann.

MAY 15.—The President in the chair. Forty-one members and visitors present.

The President reported that, by the advice of an informal conference of the Board of Directors, he had obtained House Bill No. 536, "To Regulate the Height of Buildings in Cities of the First Class." This bill was then read by the Secretary, and after discussion, was laid aside without further action.

The subject of "Modern High Office-Buildings" was discussed by Messrs. James Christie, Joseph T. Richards, A. Falkenau, W. L. Webb, T. H. Müller, E. M. Nichols, W. C. L. Eglin, J. S. Merritt, H. V. Foss and W. C. Furber.

JUNE 5.—The President in the chair. Sixty-three members and visitors present.

The Tellers reported the election of Messrs. Theodore N. Ely and Frank L. Sheppard to active membership.

Mr. J. S. Robeson read a paper on "The Bertrand-Thiel Modification of the Open-Hearth Process."

The methods of producing steel were discussed by Messrs. J. Christie and B. Talbot.

Mr. J. E. Codman read a paper on "Rainfall and Stream-Flow Observations in Eastern Pennsylvania."

ABSTRACT OF THE MINUTES OF THE BOARD OF DIRECTORS.

SPECIAL MEETING, Saturday April 10, 1897.—Present: The President, the Second Vice-President, Directors Livingston, Eglin, Hartley, Schumann and Ott; the Secretary and the Treasurer.

The meeting had been called to receive the report of the Finance Committee.

The Finance Committee presented a tabular statement of expenditures for 1896 with recommendations for expenditures for 1897. The Committee suggested that the appropriations be granted with the understanding that not more than 60 per cent of the amounts shall be available prior to October 1, 1897.

The tabular statement was amended to read as follows:

RECEIPTS.

Dues and Initiation Fees, 1896	$250 00
" " " 1897	4,655 00
Proceedings	75 00
Total Income from all sources	$4,980 00

NOTE.—Dues for 1896 not paid December 31, 1896, amounted to $500.00. Estimated amount collectible, $250.00.

EXPENDITURES.

	1896.	1897.
Salaries	$1,190 50	$1,200 00
Secretary, Office Expense	202 00	250 00
Notices	540 00	540 00
Treasurer's Office	81 30	50 00
Reprints	30 25	
House Committee, (including rent, coal, light, ice, improvements, repairs, supplies, luncheons, etc.	2,471 48	2,211 75
Information Committee	63 99	40 00
Library "	81 30	100 00
Publication "		80 00
	$4,660 82	$4,471 75

The report, as amended, was adopted.

SPECIAL MEETING, Saturday, April 24.—Present: The President, the Second Vice-President, Directors Schermerhorn, Eglin, Schumann and Ott; the Secretary and the Treasurer.

The Treasurer's Report showed:

Cash on hand	$2,171 13	
Received during March	401 60	
		$2,572 73
Expended during March		618 75
Balance on hand March 31, 1897		$1,953 88

The House Committee recommended the installation of an Exchange Telephone in the Club House, the charges for which would be $60.00 per year, for not more than 600 calls from the Club. An appropriation of $60.00 was made for the purpose.

The Information Committee reported that a programme of papers for Meetings had been arranged as far as October, but that few responses had been received to circular letters sent to all members, requesting papers.

SPECIAL MEETING, Saturday, May 22, 1897.—Present: The Vice-Presidents, Directors Livingston, Schermerhorn, Eglin, Hartley, Schumann and Ott; the Secretary and the Treasurer.

The President reported by letter that he had obtained a copy of the act before the Legislature, on the subject of the height of buildings in cities, and suggested that our Club should be represented in such a way that when laws of interest to architects and engineers are to be passed, the Club should receive a copy of such laws as a matter of information, that members might act upon them individually. It was resolved that the Board should recommend to the Club the appointment of a Committee on Legislation.

The Treasurer's report showed:

Cash on hand, April 1st	$1,953 98	
Received in April	272 48	
		$2,226 46
Expended in April		592 27
Balance, April 30, 1897		$1,634 19

The Secretary was instructed to refer any request to use the Club House directly to the House Committee, who shall have power to act thereon, and that he call the attention of members to this fact in the next few notices for meetings.

SPECIAL MEETING, June 18, 1897.—Called to take the place of Stated Meeting, June 19, 1897.

Present: The President, the Vice-Presidents, Directors Eglin, Hartley, Schermerhorn and Ott.

The Treasurer's report showed:

Cash on hand, May 1, 1897	$1,634 19	
Received during May	419 50	
		$2,053 69
Expended during May		281 62
Balance on hand, May 31st		$1,772 07

The Library Committee reported that it had purchased a book-case for the Club-Parlor. It is proposed to add reference books to the collection from time to time.

Publication Committee reported that the April number of the Proceedings had been issued after some delay. The July number is now in preparation. The following resolution was adopted:—"That the Publication Committee be empowered to revoke or amend the publication contract with Messrs. Armstrong & Fears, if in the judgment of the Committee the interests of the Club require it."

For the Information Committee, Mr. Schermerhorn stated that papers had already been arranged for, up to the end of October.

CONTRIBUTIONS TO THE LIBRARY.

FROM DECEMBER 15, 1896, TO JULY 1, 1897.

FROM WALTER G. BERG.

Discussion on the Profession of the Railway and a Suggested Course of Training Therefor.

FROM CHIEF OF ENGINEERS, U. S. A.

Annual Report, 1896.

FROM J. V. MENDES GUERREIRO.

Obras do Porto de Lisboa, Conferencias feitas em March e Abril de 1892.

FROM NOVA SCOTIAN INSTITUTE OF SCIENCE.

Proceedings and Transactions, Session of 1895–96, Volume IX.

FROM THE PATENT OFFICE, LONDON.

Patents for Inventions, Abridgments of Specifications.

FROM THE AMERICAN IRON AND STEEL ASSOCIATION STATISTICS.

American and Foreign-Iron Trade for 1896.
Annual Report of the American Iron and Steel Association.

FROM PUBLISHERS' WEEKLY, NEW YORK.

Publications of Societies.

FROM AMERICAN INSTITUTE ELECTRICAL ENGINEERS.

One Volume XIII, January–December, 1896.

FROM ARMOUR INSTITUTE OF TECHNOLOGY, CHICAGO.

Year Book, 1896–97.

FROM BOSTON PUBLIC LIBRARY.

Annual Report, 1896–97.

FROM LIBRARY, WAR DEPARTMENT, WASHINGTON, D. C.

Conclusions Adopted by the French Commission in reference to the Tests of Cements. "The Influence of Sea-water on Hydraulic Motors." Translated by O. M. Carter and E. A. Geiseler.

FROM FAIRMOUNT PARK ART ASSOCIATION.

Twenty-fourth Annual Report of Board of Trustees and List of Members. Also "Unveiling of the Memorial to General James A. Garfield."

FROM SHERARD COWPER-COLES.

The Electro-Deposition of Zinc.

FROM SMITHSONIAN INSTITUTION.

Smithsonian Report, 1894.

FROM SOCIETE DES INGENIEURS CIVILS DE FRANCE.

Inauguration du Nouvel Hôtel de la Société, January 14, 1897.

FROM THE STATE AGRICULTURAL COLLEGE, COLORADO.

Seepage or Return Waters from Irrigation.

FROM THE UNIVERSITY OF PENNSYLVANIA.

Catalogue, 1896–97.

FROM THE UNIVERSITY OF WISCONSIN.

Topographical Surveys, Their Methods and Value.

FROM S. F. PATTERSON.

Proceedings of Sixth Annual Convention Association Railway Superintendents of Bridges and Buildings, Chicago, October, 1896.

FROM W. F. MORSE, NEW YORK.

Cremation, Disinfection, Sterilization ; W. F. Morse.

FROM AMERICAN INSTITUTE OF MINING ENGINEERS.

Thirteen Abstracts from Papers of the Society.

FROM GENERAL HERMAN HAUPT.

Compressed Air and Electricity; Herman Haupt.
Compressed Air for City and Suburban Traction ; Herman Haupt.
Long Distance Transmission of Power ; Herman Haupt.

FROM JOSEPH T. RICHARDS.

Engineering Directory (May), London, England.
Record of Transportation Lines, Pennsylvania Railroad, 1896.

FROM W. S. AUCHINCLOSS.

" Waters within the Earth and Laws of Rain-flow." By W. S. Auchincloss.

FROM ALABAMA INDUSTRIAL AND SCIENTIFIC SOCIETY.

Proceedings. Vol. VI, Part 11, 1896.

FROM U. S. COAST AND GEODETIC SURVEY, WASHINGTON, D. C.

Annual Report of the Superintendent for the year 1895.

FROM MISS CLEEMAN.

Nystrom's Mechanics.
Long-Span Railway Bridges; B. Baker.
Civil Engineering; Prof. Rankine.
Applied Mechanics.
Bridging the Mississippi River between St. Paul and St. Louis; Warren.
The True Figure and Dimensions of the Earth ; J. Von Gumpach.
The Water-Works of London ; Colburn & Man.
Treatise on Compound Ordnance ; Polliser.

THE ENGINEERS' CLUB OF PHILADELPHIA.

HOUSE, NO. 1122 GIRARD STREET,

PHILADELPHIA, PA.

OFFICERS FOR 1897.

President,

JOSEPH T. RICHARDS.

Vice-Presidents,

Term Expires January, 1898. CARL HERING.

Term Expires January, 1899. HENRY LEFFMANN.

Directors,

Term Expires January, 1898.

L. Y. SCHERMERHORN, MAX LIVINGSTON, C. H. OTT.

Term Expires January, 1899.

W. C. L. EGLIN, GEO. B. HARTLEY, F. SCHUMANN.

Secretary,

L. F. RONDINELLA.

Treasurer,

GEORGE T. GWILLIAM.

STANDING COMMITTEES OF BOARD OF DIRECTORS.

Finance—W. C. L. EGLIN, MAX LIVINGSTON, HENRY LEFFMANN.
Membership—L. Y. SCHERMERHORN, GEO. B. HARTLEY, C. H. OTT.
Publication—HENRY LEFFMANN, CARL HERING, L. Y. SCHERMERHORN.
Library—GEO. B. HARTLEY, HENRY LEFFMANN, F. SCHUMANN.
House—C. H. OTT, W. C. L. EGLIN, MAX LIVINGSTON.
Information—F. SCHUMANN, L. Y. SCHERMERHORN, CARL HERING.

MEETINGS:

Annual Meeting—3d Saturday of January, at 8 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets at 4 P.M. on the 3d Saturday of each month, except July and August.

The New Delaware Breakwater.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.
INCORPORATED JUNE 9, 1892.

Vol. XIV.] OCTOBER–DECEMBER, 1897. [No. 3.

XII.

BREAKWATER CONSTRUCTION ON THE AMERICAN COAST.

By LOUIS Y. SCHERMERHORN, M. Am. Soc. C. E., Active Member.

Read October 16, 1897.

UNDER the subject which will be presented to you this evening, reference will be confined to that class of breakwater constructions which belong to the ocean coast of our country, thereby omitting any detailed allusion to breakwater construction upon the great lakes, where the conditions surrounding the problem are so widely different from those belonging to the ocean coast, that but little correlation exists between them.

Without a definition there might be some misunderstanding as to the class of constructions to which reference will be made, since we find that the terms breakwaters, jetties, and piers, are sometimes confusingly used. A breakwater is an artificial structure, providing a harbor or roadstead with protection against waves, and differs from the other constructions named, in that it is essentially a wave-breaker.

Breakwaters, through their object, may be divided into two classes, viz., those which give shelter and protection to commercial harbors or their entrances; and those sheltering an anchor-

age or roadstead: the latter are denominated *harbors of refuge*, and are only used by vessels in transit, which have occasion to escape from the violence of passing storms. Each of these classes might be technically further divided according to their particular type of construction; which in turn is decided by the question of initial or ultimate economy, with due regard to effectiveness. For example, where durable rubble stone could be cheaply obtained the breakwater would probably consist of random stone, of suitable sizes, deposited in the form of an embankment, or mound. Where such stone could only be obtained at considerable cost, concrete blocks might be substituted, and either deposited as the random stone would be, or in the form of a massive and regular wall; or the stone might be used for a substructure surmounted by the concrete blocks as a superstructure. The latter form has been extensively used abroad; but has never been adopted, though frequently considered, upon the ocean coast of our country.

An abundance of durable stone, convenient to the coast, is to be found along that part of the Atlantic north of Cape Hatteras, and along the Pacific coast. This fact, supplemented by the modern methods of cheap quarrying and handling of stone, has made its use much more economical than that of concrete blocks, and has thereby decided, in this country at least, the question in favor of random stone for breakwater construction along our ocean coast.

The limits of this paper will not permit more than a passing reference to the forces impressed upon breakwaters through wave-action; but brief allusion thereto becomes necessary, since the amount and direction of these forces must be carefully considered before the proper design, and position of the breakwater can be adopted, or the general principles of breakwater construction understood.

In the problems of the engineer, the maximum force likely to be impressed upon the structure determines the necessary stability to be given the construction. While it is difficult to estimate, except approximately, the force or impact of breaking waves, observation and experience furnish some data for deductions. The English engineer, Thomas Stevenson, followed by others, has

furnished the results of experiments, through the aid of marine dynamometers, which assign values to the wave forces to be met and resisted. These observations recorded pressures in the North Atlantic of 6,000 pounds per square foot; and in the German Ocean of 3,000 pounds. M. Le Ferme, from the destruction of the beacon at the mouth of the Loire, calculated that the wave forces impressed upon the work must have exceeded 4,800 pounds, and probably approximated 6,000 pounds per square foot. The most remarkable observed instance of the power of waves, was afforded by the movement of a solid mass of masonry, set in cement in the form of a massive block, weighing 1,350 tons at the end of the Wick-Bay breakwater. The mass, 45 feet wide, 26 feet long and 21 feet high, was completely turned around upon its base, and at last tilted off its foundation.* Extraordinary as this may appear it was subsequently surpassed when another concrete block, substituted for the one just described, was in like manner carried away, though it contained 1,500 cubic yards of concrete masonry, and weighed about 2,600 tons.

In 1884, Mr. William P. Judson, C.E., made some observations upon Lake Ontario at Oswego, N. Y., to determine the height, velocity, and impact of the waves upon the breakwater at that locality, with the following results: during a severe northwest gale, the waves at a distance of 1,000 feet outside the breakwater, attained a height of from 14 to 18 feet above the normal surface of the lake, with a velocity of from 30 to 40 miles per hour. Dynamometers attached to the face of the breakwater at depths of 8 feet below the surface, at the surface, and 8 feet above the surface, recorded pressures, respectively, of less than 10 pounds, 600 pounds, and at the higher elevation about 1,000 pounds per square foot.

The instances referred to are the maximum forces which have been observed, but, since they depend upon local conditions, cannot be assumed as those which are to be the standard in all cases. The height and force of impinging waves at any locality depend upon the force and duration of winds, the depth of the water, the *fetch* or distance over which the waves move, and the angle of incidence at which they strike the breakwater.

* *Harbor and Docks*, Harcourt, pages 28, 31.

Theoretical considerations indicate that the energy of the impact of waves varies as the cube of the waves' height. Stevenson, from observation, developed the empirical formula, $h = 1.5 \sqrt{d}$, for the determination of wave-heights, which is considered as representing with tolerable accuracy the heights of waves during heavy gales, in which h is height in feet, and d the fetch of the waves in miles.* The results of this formula for low values of d are somewhat [illegible] small, while for large values of d they are too great. Scott [illegible]ssell considers that 27 feet is the greatest height of waves in the British seas; and Sir G. Airy, from theoretical consideration, concludes that from 30 to 40 feet would be the extreme height of unbroken waves, except under rare conditions. Dr. Scoresby observed waves in the mid-Atlantic which averaged 26 feet in height, and moving with a velocity of over 30 miles per hour, while the highest wave he estimated to have a height of 43 feet. Waves have been observed off Cape Horn with a height of about 50 feet. Previous to the laying of the first Atlantic cable, an effort was made to carefully collate the most reliable information upon this point; the result was that 50 feet was considered as the extreme height of waves in the open sea.

On the assumption that, at the instant of breaking, the vertical section of a wave at the surface is a common cycloid, and that the height, d, of the wave is not greater than the depth of water in which it moves, theoretical considerations indicate that the maximum wave-energy, in foot-pounds per linear foot of the wave crest, $= \frac{64\pi d^3}{32} = 2\pi d^3$; the weight of a cubic foot of sea water being taken at 64 pounds.† For wave-depths of 10 feet, this gives an energy of 6,300 foot-pounds, and, for wave-depths of 15 feet, about 21,000 foot-pounds. If the form of the wave at the moment of breaking is that of a prolate cycloid, as some authorities assert, its energy would be about 60 per cent. greater than that above stated. While such calculations are more curious than valuable, they nevertheless serve to convey some idea of the forces impressed upon breakwaters by wave-action.

* *The Design and Construction of Harbors,* T. Stevenson, page 25.

† *Report, Chief of Engineers,* 1889, page 1321.

The destructive effect of waves of translation also depends greatly upon the angle of incidence between their line of impact and the axis of the breakwater, and, other conditions being equal, this force of impact will vary with the sine-square of the angle of incidence. At Wick it was found that by changing the direction of the axis of a part of the work, so as to reduce this angle from 90° to about 80°, the breakwater withstood the action of waves, which previously had been such as to repeatedly destroy the work.

From this brief consideration of the wave-forces impressed upon a breakwater, it is evident that its design, from the standpoint of stability, must depend upon conditions arising from the location of the work. In the case of random-stone breakwaters, this question of stability depends upon the cross-section of the work, and the dimension of the stone used upon the active slopes.

Such a breakwater essentially consists of two parts, viz., the substructure or that part below the surface of the water, and the superstructure or that above water. The wave-action which it is necessary to arrest by a breakwater does not extend to a great depth below the surface of the water; therefore, the superstructure and the upper part of the substructure are the effective parts of the breakwater, as well as the parts of the construction which are subjected to the most destructive action of the waves. A large part of the substructure, therefore, becomes simply a means of supporting the superstructure, and the limited part of the substructure which is exposed to marked wave-action. In general terms, the necessary dimensions of the superstructure and the upper part of the substructure, determine the dimensions of the remainder of the work. While the superstructure must resist severe wave-action, it must likewise preserve the needed tranquillity of the areas behind it, by being carried to a height sufficient to prevent waves being thrown unduly over the top of the structure.

The bounding surfaces of a random-stone breakwater consist approximately of plane surfaces, forming the top, bottom, and sides: the latter, at more or less of an inclination dependent upon the special part of the work to which they belong, are

called the slopes. One side of the work is exposed to the action of the sea, while the opposite side rests in the comparatively quiet water of the protected area. The sea face of the work, while receiving and arresting the energy of the waves thrown upon it, is not, from the limited depth of wave-action, exposed throughout all of its depth to the same amount of destructive force; therefore that side of the breakwater need not be provided, for its entire depth, with the same measure of stability.

Experience upon American breakwaters has determined that the depth to which energetic wave-action extends, is about 12 or 15 feet below the surface of water; and this depth is generally assumed, upon our works, as the approximate *plane of rest* for the material which is used. Since our breakwaters are all placed in tidal waters the position of this plane must vary with the amplitude of the tide, which in the breakwater locations to be referred to is between 3 and 8 feet. Upon leading European breakwaters, of nearly the same type as those under consideration, the increased exposure of their sites, and the height of ocean waves impressed upon the works, lowers the plane of rest to a depth of about 20 feet below the surface of the water; while the tidal range of their localities is nearly double that above given for American breakwaters. It is evident that these facts must materially change the details of American and European practice.

In a qualified sense, the so-called *plane of rest* is more of an abstraction than a well-observed and established fact, and it should not be inferred, from the use which is made of this term, that a clearly defined depth-limit to the disturbing effect of wave-action can be undeniably assumed, within the limits usually ascribed to this plane. It is true that a point must exist in a wave's depth where the impulsive force is a maximum, and it is equally true that upwards and downwards from this point the force must decrease; but the law of this decrease does not permit the conclusion that wave-action entirely ceases at the depths assigned to the plane of rest in breakwater construction. It simply means that at the assumed depths the disturbing effect of the waves has been so reduced that it is no longer able to move the special stones constituting the slopes at such depths.

If these stones were larger the plane of rest would be raised, and conversely, if they were smaller it would be lowered.

From the foregoing consideration the slopes of a random stone breakwater may be divided, from the forces impressed upon them, into the following: (1) that part of the sea face which is below the plane of rest; (2) that part which is between the plane of rest and the surface of the water; and (3) the part above the surface of the water. On the harbor side but two divisions of the slope need consideration, viz., that below, and that above the water surface. Upon the sea face below the plane of rest, the random stone will assume a slope coincident with the angle of repose of the material, unaffected by wave-action; on that part between the plane of rest, and the surface of the water, the slope will be formed by wave-action, modified somewhat by the dimensions of the stone constituting the slope; while above the surface of the water, both on the sea and harbor faces of the work, the slopes will be artificial, and dependent upon the size of the stone and the care with which they are laid. On the harbor face where the structure is not exposed to wave-action, the slope from the surface of the water to the bottom will be that of the angle of repose of the material. These several slopes, as determined by experience and practice, will be considered later.

Where the wave impinges upon a nearly vertical surface, the wave is thrown to a considerable height, and in falling is reflected, in part, seaward; while experience indicates that a talus causes the wave to break and thereby dissipate its energy upon the sloping surface on which it impinges; this is said to be fully realized when such a slope is about 1 on 3. Upon the vertical face type of breakwaters waves have been observed as thrown to a height of 200 feet; this fact serves to strikingly illustrate the energy contained in waves, and the stresses brought upon the construction in the arrest of wave-force.

Upon any slope less than the angle of repose of the material, the size of the stone determines largely the stability of the slope to resist forces tending to disturb its equilibrium. In general terms such stability increases with the dimensions of the stone used; and, within proper limits, the active slopes of the breakwater may be increased—with a proportional reduction of the

aggregate volumes of material used in the work and a consequent reduction in cost—by the use of larger individual masses of stone in these slopes. The limit of such economy is reached however when the increased cost of larger stone equals the saving in the cost of the aggregate volume of stone used in the work. This has led in European practice to the use of immense blocks of concrete upon the most exposed part of the sea slopes of random-stone breakwaters.

The dimensions of the stone used in the active slopes of the substructure usually vary between 2 and 5 tons, with smaller stone constituting the interior volume of the work. Since the superstructure is above the surface of the water it permits of the cheap application of labor to the orderly arrangement of the stone constituting its mass, whereby a saving in volume, and consequent cost, is obtained by using very large stones, laid with some approximation into the form of a rough, though strong and heavy wall. Upon this part of the work stones weighing from 3 to 10 tons each are used on the sea and harbor faces, with a core of somewhat smaller stones.

Under American experience and practice the general slopes of the several parts of the sea and harbor faces are as follows:

Sea face below the depth of 12 to 15 feet	1 on 1 to 1 on 1.5
" " from 12 to 15 feet depth to low water	1 on 3
" " from low water to top of superstructure	1 on 0.7 to 1 on 1
Harbor face from bottom to low water	1 on 1 to 1 on 1.3
" " from low water to top of superstructure	1 on 0.7 to 1 on 1

The superstructure usually has a width on top of about 20 feet, and with the slopes above given the dimensions of the resulting cross-section of the entire structure become dependent upon the height of the superstructure, and the depth of water in which the breakwater is placed. Upon the two most recent works, viz., the breakwater for the National Harbor of Refuge in Delaware Bay, which is now in progress, and the proposed breakwater for the Harbor of Refuge on the coast of Southern California at San Pedro, the top of the superstructure is placed at a height of 14 feet above the plane of low water. With these dimensions for the superstructure and the slopes above given, the breakwaters at the localities named obtain a width of about 40 feet at the plane

of mean low water, and about 90 feet at the assumed plane of rest, 12 feet below the plane of low water.

The most typical random-stone breakwaters of the ocean coast are at Sandy Bay, Cape Ann, Mass.; Point Judith, R. I.; and Delaware Bay, Del. A second breakwater is in progress of construction in Delaware Bay; while the report of a recent Board of Engineers decides upon San Pedro Bay, California, as the proper site for a breakwater to give protection to deep-water commerce, and furnish a harbor of refuge for the South California coast.

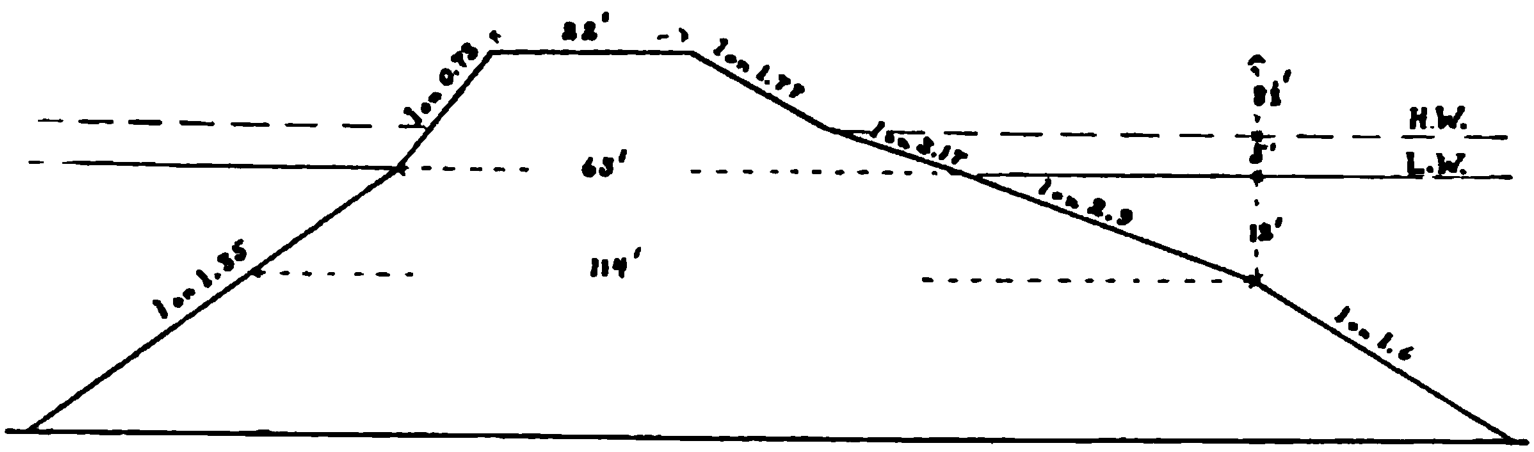
The Delaware Breakwater had its inception in a plan submitted in 1828, by a Board of Commissioners appointed by Congress. The project proposed the construction of two massive works, on the *pierres perdue* or rip-rap system, separated by an interval of 1,390 feet; the larger work, called the breakwater, to afford safe anchorage during gales from the North and East; and the lesser, called the ice-breaker, to protect shipping against northeast gales, and the heavy drifting ice of the bay. These works were commenced in 1828, continued under regular appropriations until 1840; resumed after the war in 1866, and completed in 1869. The aggregate amount expended was $2,192,103, which resulted in the construction of 2,558 feet of breakwater, and 1,359 feet of ice-breaker. In 1882 a project was adopted for closing the gap between the two detached works; and in 1883 work was commenced thereon. At the present time this work is in progress and will probably be completed at an early date, whereby the entire construction will attain a length of slightly more than one mile. The cost of the entire work will be about $3,000,000.

A careful study of the Delaware breakwater has furnished details of great value to those who have in late years been called upon to consider such constructions; some of these details refer to the sea and harbor slopes of the breakwater, and others to the ultimate relation between the volume of stone in the work, as determined by subsequent exact surveys, and the tonnage of stone placed therein.

By combining a large number of sections of the breakwater, as determined by careful survey, the present slopes of the work may be classified as follows:

Plane of rest—sea face—at depth of 12 feet below low water:

Sea face slope below plane of rest	1 on 1.6
" " " between plane of rest and low water	1 on 2.9
" " " between low and high water	1 on 3.17
" " " between low water and top of superstructure	1 on 1.77
Harbor face slope between bottom and low water	1 on 1.35
" " " between low water and top of superstructure	1 on 0.73



SECTION OF OLD DELAWARE BREAKWATER.

It should be noted that the slopes directly above and below low water line, on the sea face of the work, vary but slightly from each other; the lower slope being 1 on 2.9 and the upper 1 on 3.17, or respectively about 19° and 17½°. This slight difference of about 1½° is probably within the error of determination, and without serious error the entire slope between the plane of rest and the base of the superstructure can be taken as about 1 on 3. The assumption that the plane of rest occurs at 12 feet below low water is simply derived from the evidence of these slopes.

These slopes are graphically shown on the section below.

The mean cross-section of the first Delaware breakwater has the following dimensions:

	Feet.	Inches.
Width at top of superstructure	22	0
Height of superstructure above high water	8	6
Difference between high and low water	5	0
Width at high water	43	0
" " low "	62	9
" " plane of rest	113	9
" " bottom	166	0
Total mean height	43	6
Mean cross-section, in square feet	4,100	

The ice-breaker, which from its position is much less exposed to the action of the waves, has a slope upon the sea face of 1 on 2, and on the harbor face of about 1 on 1.3; the mean cross-section of the ice-breaker is about 3,600 square feet.

The calculated volume of the breakwater and ice-breaker, including voids, as determined from surveys, was 595,000 cubic yards. The quantity of stone delivered in the works was 892,-528 gross tons. These figures would seem to indicate that 1.5 gross tons were required for each cubic yard of volume of the breakwater.

The foundation of the works must have sunk somewhat into the bed of the harbor, through the weight of the mass; recognized scour at the ends of the structure caused considerable material to fall into these holes; while other material has probably been carried by the sea outside of the limits of the work. These volumes have been omitted by the survey, and consequently have given too small a mass for the material deposited in the work. A survey of the material deposited in the gap between the breakwater and ice-breaker gave 1.17 gross tons per cubic yard of enrockment; while the careful measurement of a large volume of stone weighed onto barges gave 1.15 gross tons per cubic yard of volume. Observation derived from rock in settled railroad embankments give about 1.18 gross tons per cubic yard of space occupied.

From these considerations, Major Raymond derives the conclusion that 1.25 gross tons per cubic yard of random-stone embankment is an ample allowance for each cubic yard of breakwater after the settlement of the mass, and any loss of stone which may occur.* The stone which has been used in the Delaware breakwater weighs from 160 to 170 pounds per cubic foot.

The Delaware breakwater has been the prototype for all other accomplished or proposed random-stone breakwater construction upon our ocean coast; and while its details have not been exactly repeated, the experience gained upon the work has been utilized both in design and construction at all other localities. The early records of this work seem to indicate that the Board of Commissioners, who designed the breakwater in 1828, were materially influenced by the dimensions and slopes used upon European breakwaters at that date, and that its foundation width was based upon anticipated slopes such as would be

* Report of Chief of Engineers, 1891, page 1081.

derived from the examples then before them; therefore, it cannot be correctly assumed that the cross-section of the Delaware breakwater of to-day is exactly the result of slopes derived from the action of the wave forces which have been impressed upon them. The history of the work indicates that, at some time after its commencement, those in charge probably abandoned the idea of following the early adopted cross-section, and in place thereof sought to obtain such slopes as would result directly from the action of the waves; therefore, it follows that probably the resulting cross-section of the work of to-day is a compromise between anticipated and realized slopes upon the several parts of the structure.

The active sea slopes of the Portland, Plymouth and Cherbourg breakwaters vary from 1 on 4 to about 1 on 8; while, as previously noted, the flattest slopes of the Delaware breakwater are about 1 on 3. In this respect it presents a striking contrast to European breakwaters in the steepness of its active sea slopes. While the Delaware breakwater is not exposed to the force of seas such as are thrown upon the European works named, it is highly probable that its slopes, through the method by which they have been obtained, are more nearly in equilibrium with the forces which are impressed upon them than obtains in the European cases referred to.

It is evident that the maximum economy in random-stone breakwater construction is realized when the slopes, and consequent cross section, are such as to place the work in simple stable equilibrium with the forces which it is to resist. Any additional material beyond this would be unnecessary and, therefore, an extravagance. To secure a stable section, and at the same time provide that it shall contain the minimum volume of material, requires that its method of construction should be carried on in the three following stages: (1) The formation of the volume below the plane of rest; (2) the deposition of the volume between the plane of rest and the base of the superstructure; (3) the construction of the superstructure. This order of construction has been developed and carried into practice by Major C. W. Raymond, Corps of Engineers, U. S. Army, who has present charge of the completion of the Delaware breakwater, and also the construc-

tion of the new breakwater in Delaware Bay. Major Raymond's extended experience in breakwater construction on the ocean coasts of the United States, placed him upon the Board of Engineers for the location and plans for a harbor of refuge upon the coast of southern California; and upon his plans and specifications the several reports upon this important work have been mainly based.

Under the order of construction above indicated the deposition of the random stone is confined strictly to a width and depth conforming to the width and depth of the cross-section of the breakwater at the assumed plane of rest; by this method the material on the slopes is forced to assume the steeper angles of repose which properly adhere to this part of the work; at the same time the initial settlement of the foundation and this part of the mass is secured.

When this lower section of the breakwater is completed it is followed by the second stage, the formation of the mass between the plane of rest and the base of the superstructure, by the deposition of all material within the width of the base of the superstructure; care being taken in this important section to deposit the larger stone upon the sea side of the breakwater. This brings the construction within the disturbing action of the waves; and as this part of the work progresses the stones upon the sea face of the work assume such slopes as to place the work in actual equilibrium with the wave forces impressed upon it; thereby leaving to the sea the task of largely declaring the slope and consequent stability which is required to meet the peculiar conditions of the exposure. If the engineer, for any reason, has erred in judgment by assuming too steep slopes, the action of the sea revises his calculations, and, beyond the possibility of mistake, corrects the error. It is evident that by this method the minimum volume of section, and consequent maximum economy of cost, consistent with required stability is obtained.

By the time the entire breakwater has been completed to the height of the base of the superstructure, an opportunity has been given this part of the work to thoroughly settle, so as to be in condition to receive the construction of the superstructure, which is not undertaken until a condition of stable equilibrium has

been attained by the substructure, and its upper surface carefully levelled to receive the superimposed mass.

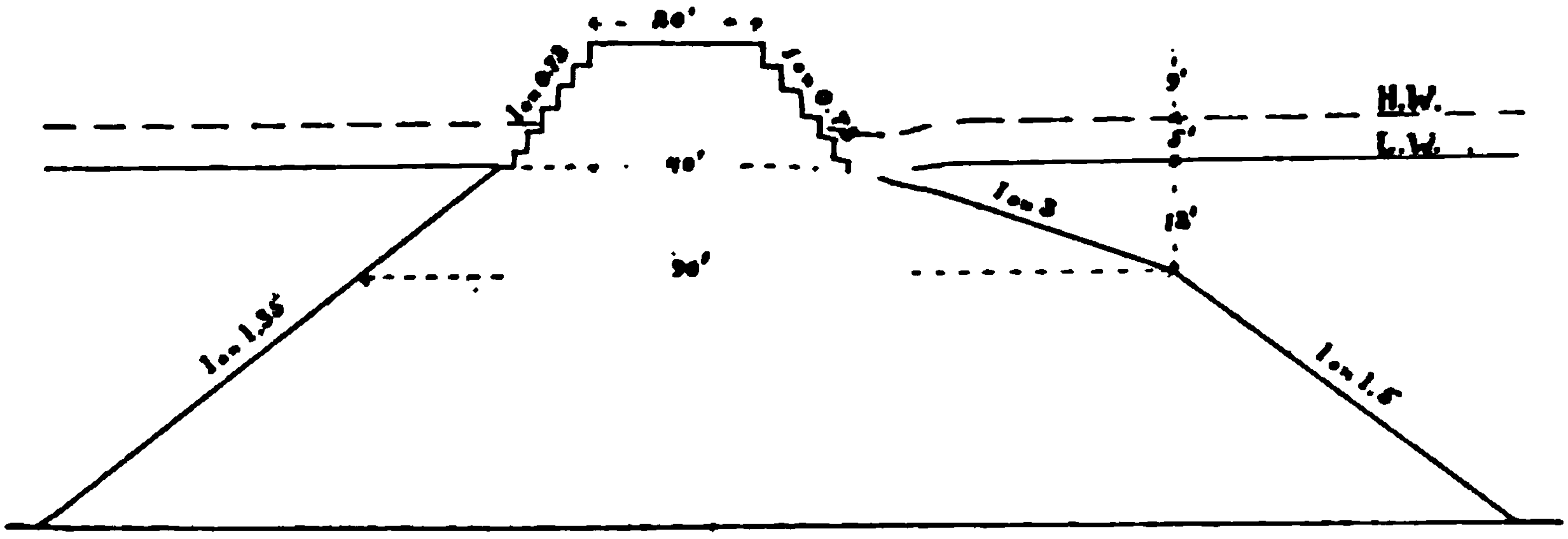
The superstructure, in the most recent types of American random-stone breakwaters, consists of rough, strong walls upon the sea and harbor faces of the work, built of larger stone systematically placed, so as to secure a strong bond; the space between these walls being filled with stone varying in size so as to form a compact mass without large interstices. This part of the work requires the use of powerful derricks for handling and properly placing the large stone constituting its mass. Under the methods above outlined, the several widths of deposits for the random stone are marked by carefully placed ranges, and within their limits all material is strictly deposited. In this respect the practice now varies greatly from that of former times, when wide latitude was given to the areas upon which the stone was initially deposited in the efforts, then in vogue, to form predetermined slopes through the deposit of stone directly upon such slopes.

Until later times it has been the practice to transport the stone to the site of the work, upon sailing vessels, deck-scows, barges or any other available means of water transportation: this necessarily resulted in more or less of a haphazard method of discharge and deposit, arising from the fact that the vessels used were not fitted with machinery and appliances for quickly and accurately placing the stone in the work. Such methods unquestionably resulted in considerable waste of material through its not being deposited exactly upon intended areas.

Under the methods now in operation upon the new breakwater for a National Harbor of Refuge in Delaware Bay, the material below the assumed plane of rest, as well as a part above this plane, is transported to the work in dump scows of 1,400 tons capacity, and specially arranged construction, whereby the entire load of such scows is released at once, and, without the intervention of labor or machinery, deposited, *en masse*, through the bottom of the scows directly upon the width of section on which the material is desired. Besides ensuring accuracy of deposit, the abolishment of the former large element of hand-labor in the discharge of stone, permits the unloading of these scows during a

rough condition of the sea, when under past methods it would have either been impracticable, or if attempted, resulting in an uncertain and unsatisfactory deposit of the material upon areas probably somewhat removed from those on which the stone should have been deposited. The remainder of the plant for the delivery of the stone in the new breakwater consists of large seaworthy barges, of 1,500 tons capacity each, provided with powerful steam derricks, capable of handling 15 tons, for quickly and certainly placing the stone at desired points.

The breakwater for the National Harbor of Refuge in Delaware Bay, which is now in progress, a section of which is shown below, is located outside of, and nearly 2½ miles north from, the existing breakwater. It is placed in water from 13 to 53 feet deep, has a length of about 1½ miles, and covers a protected anchorage, against the heaviest storms, of 552 acres with a minimum depth of 30 feet, and an additional area of 237 acres with a minimum depth of 24 feet. These combined areas would give free and good anchorage to more than 1,000 vessels. The work is esti-



Section of New Delaware Breakwater.

mated to contain 1,384,000 net tons of stone, and will cost, with the projected ice piers, probably about $2,500,000. Although only commenced during the present season, the specifications for the work require its completion by December 31, 1901, through the annual deposit of about 280,000 tons of stone. Since the prevalence of severe or stormy weather practically reduces the working season, available for depositing material in this breakwater, to about seven months for each year, it follows that an average output of 40,000 tons per month must be provided for by the contractor.

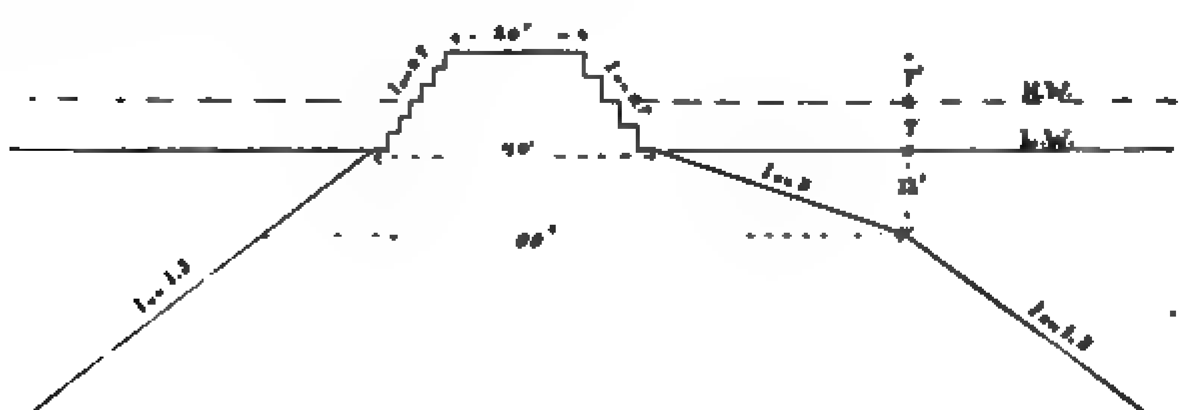
The work is being executed at this rate, which is far beyond anything ever before attained in earlier breakwater construction.

Structure of New Delaware Breakwater.

The average price paid for stone in the old Delaware Breakwater was about $2.50 per gross ton. Under the existing contract for the construction of the new breakwater, which covers the entire completion of the work, the price is $1.18⅝ per net ton.

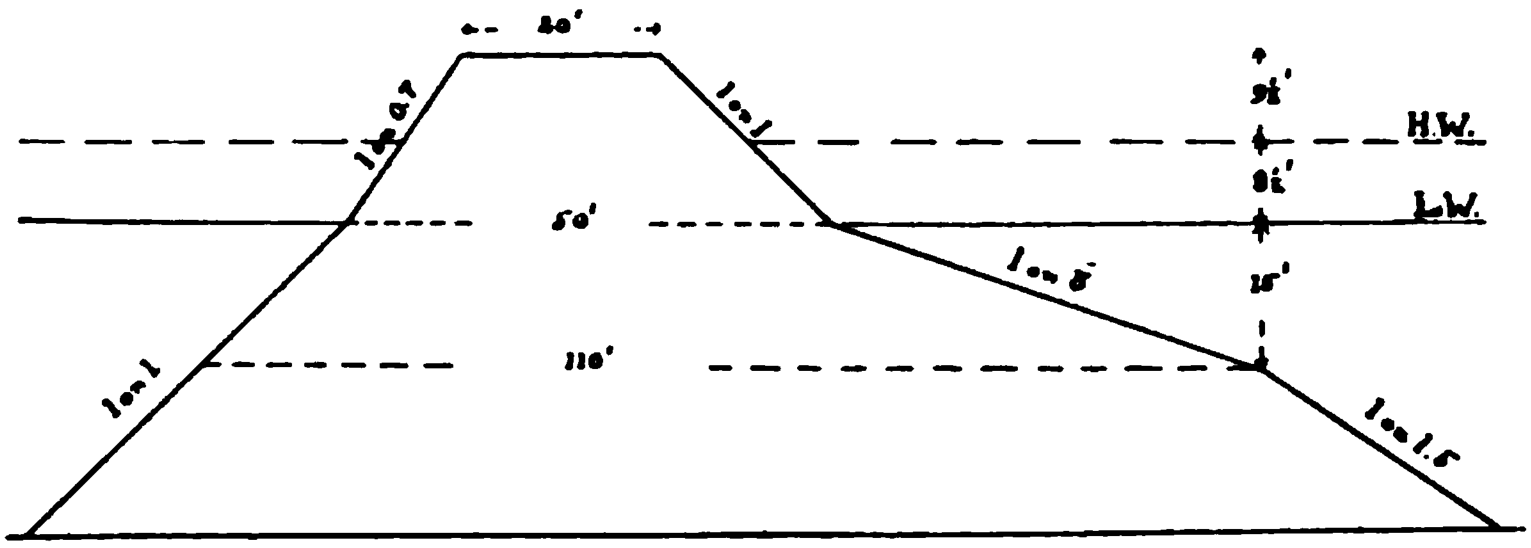
The proposed breakwater for the projected Deep Water Harbor at San Pedro, California, a section of which is shown below, is located in water from 19 to 51 feet deep. It has a projected length of 8,500 feet, and covers an anchorage area of 615 acres, with depths varying between 24 and 36 feet. The work is estimated to contain 1,782,000 cubic yards of stone, or 2,290,000 gross tons The material in the substructure below the plane of rest is estimated at $1.25 per cubic yard; that above the plane of rest at $1.50 per cublic yard; and the stone in the superstructure at $3.00 per cubic yard The entire estimated cost of the work, including contingencies, is $2,901,000.

The National Harbor of Refuge at Sandy Bay, Mass., a section



Section of Proposed Breakwater, San Pedro, Cal.

of which is shown below, was commenced in 1885, and is still in progress. It has a projected length of 9,000 feet, and covers an anchorage area of 1,377 acres, carrying a mean low-water depth of 24 feet and over. The material below the plane of rest, which in this case has been assumed at 15 feet below water surface, consists of stones not exceeding 4 tons in weight; while the portion above low water requires stone not less than 4 tons and averaging 6 tons in weight. The contract prices paid for the stone already deposited in the work have been from 60 to 75 cents per net ton. The larger stone comprising the superstructure will greatly exceed the foregoing prices: the proximity to the work of large granite quarries has permitted the exceptionally low prices paid for the stone. The estimated cost of the entire project is $5,000,000.

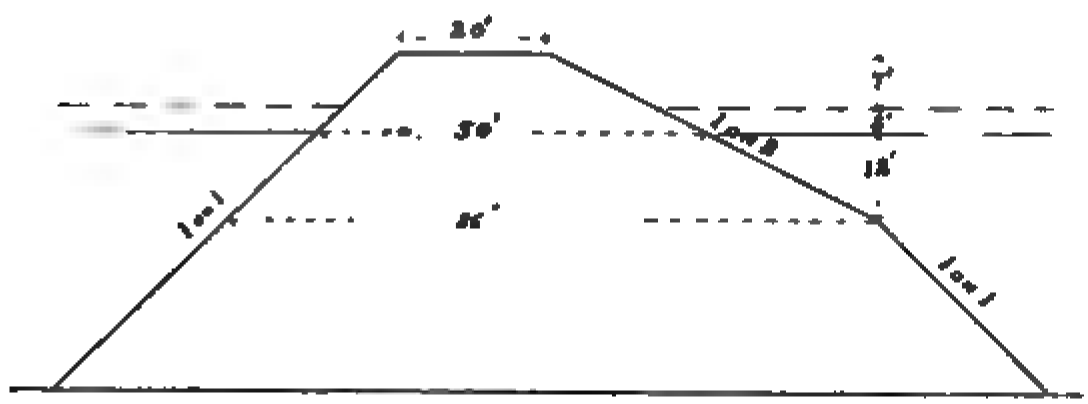


Section of Sandy Bay Breakwater.

The breakwater at Point Judith, R. I., a section of which is here shown, was commenced in 1890, and is still in progress. It has a proposed length of about 10,000 feet, including an auxiliary breakwater protecting one of the entrances to the harbor. The protected area, carrying 18 feet depth and over, is about one square mile. The work is built in water from 18 to 30 feet deep and its estimated cost is $1,250,000. In 1893 the government contracted for the entire completion of the work at the rate of $1.28 per net ton for all stone required.

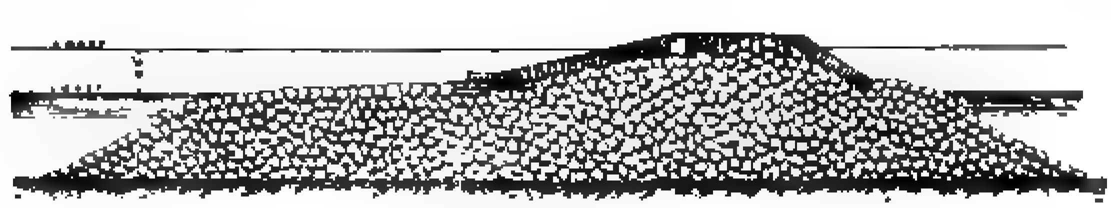
By way of comparison, the following sections of European breakwaters illustrate the difference between American and European practice in the construction of random-stone breakwaters, as well as the marked variation in the active slopes of

such works. It should not be too strongly assumed that slope variations are due, in all cases, to corresponding differences in the forces impressed upon the active slopes; since such variations are partly due to preconceived ideas as to the necessities of the case, the dimensions of the stone used, and the methods by which the slopes were formed.



SECTION OF POINT JUDITH BREAKWATER.

In addition to the constructions upon the American ocean coast before referred to, random-stone breakwaters exist at Glocester and Hyannis harbors, Mass., and at Stonington and New Haven, Conn. These breakwaters are only typical of their localities since they are not designed to cover areas which would give protection to the larger class of ocean vessels, but rather to the coastwise commerce of their vicinities.



PLYMOUTH, ENGLAND.

HOLYHEAD, WALES.

All breakwater construction in this country has been carried on under governmental appropriations made by Congress at

intervals of one or two years. The separate appropriations were seldom more than five or ten per cent. of the estimated cost of the work, and until recently competitive bids were received, and contracts entered into, for the expenditure of each specific appropriation. Under this system each contractor was obliged to add to the cost of the work, and thereby to its cost to the government, the initial expenses of obtaining and opening quarries, and providing the special plant required, and with each change of contractors the government paid for the expense of organizing, fitting out, and starting another. Under the limited tenure with which the contractor held the work, it was impracticable for him to adopt methods and appliances upon a scale large enough to permit the work being carried on with economy to the contractor, and consequent advantage to the government.

PORTLAND, ENGLAND.

CHERBOURG, FRANCE.

In a construction of the magnitude of the breakwaters described, involving the quarrying, handling, transportation, and deposit of several million tons of stone, it is evident that the work can be most economically accomplished when the amount to be done under a specific contract is so large as to justify such an initial outlay for facilities and plant, as will permit the work to be carried on upon a large scale. This has been rendered

possible upon the Point Judith breakwater, and also upon the new breakwater in Delaware Bay, by Congress providing for a single contract for the entire work at each locality, under large annual appropriations, whereby the works can be completed in about five years. By this plan, the contractor is justified in providing appliances and methods for carrying on the work upon a scale which could not be approximated under the former method of separate contracts for each specific appropriation. The resulting economy to the government is evidenced by the fact that, under the former methods of contract, the average price of stone deposited in the old Delaware Breakwater was about $2.50 per ton, and that delivered during the last thirteen years about $2.30 per ton; whereas the work now in progress upon the new breakwater, at nearly the same locality, costs the government, under the method of continuous contract, $1.18½ per ton, or a saving over former prices of nearly 50 per cent.

Harbors of refuge are but seldom used by the larger class of ocean steamers, for, unless disabled by accident, they are generally competent to pursue their way during a storm, or else ride out a gale in the open sea, with comparative safety; and unless engaged in the coastwise trade, they would seldom be in a position to avail themselves of the protection of a harbor of refuge, even if it was desired. With sailing vessels, or steamers carrying barges in tow, and coastwise commerce, such harbors are of the greatest utility, and they are placed at localities which make them most convenient of access to this class of commerce when approaching or leaving our ocean coast. During head winds, or upon the announcement of dangerous approaching storms, the sailing, barge and coastwise commerce have great need for harbors of refuge and they are utilized to their full value.

DISCUSSION.

John Birkinbine, Jr.—This able and thorough paper upon the construction of breakwaters is entitled to a full discussion, which unfortunately I am not in condition to undertake, but will confine my participation to the presentation of a suite of photographs, showing the completed portion of the breakwater at the harbor of Marquette, Michigan, on Lake Superior.

The design of this breakwater was brought to the notice of the Club two years ago, and a cross-section of it appeared on page 316, vol. xii (1895–6). The original breakwater, which has a length of 300 feet, consisted of a series of cribs, filled with stone, and the superstructure of this has been removed for the renewed portion to a depth of two feet below mean water level, and upon this a series of concreted blocks have been moulded in place, the blocks being the full cross-section of the superstructure, and ten feet in width. During the construction of this breakwater, a storm of unusual severity prevailed, and although some of these blocks were but two days old, and stones were constantly hurled against them by the waves, there was no indication of damage, except slight surface abrasion. Some of the photographs illustrate dimensions of the waves, which, on Lake Superior, sometimes rival those of the ocean. An instance, illustrating this, may be given. A young man, standing on Presque Isle, which defines the north shore of Marquette harbor, near the face of a cliff about 50 feet high, was overwhelmed, carried out into the lake, and drowned by the action of the waves breaking upon this cliff. Other illustrations show the conditions during the severe winter weather, when the breakwater has been covered with ice in masses, and in fantastic forms without serious injury.

Another photograph, taken in January, 1897, with the temperature 18° below zero, graphically shows the vaporization at the surface of the lake.

This concrete breakwater was constructed by Mr. Clarence Coleman, Assistant United States Engineers, from plans drawn by Major Searles, United States Army, and would seem to offer an excellent opportunity to determine the value of concrete monoliths moulded in place for breakwaters.

I thoroughly agree with Mr. Schermerhorn in the views which he has expressed, concerning the marked economy which is directly creditable to the adoption of continuous contracts in government work. This certainly has been of material service in advancing the river and harbor improvements on the great lakes.

James Christie.—For submarine work of this character, in localities where stone is not readily obtained, would it not be practicable to use sand, with a binding material of twigs or brush, such as was used in the Mississippi jetties? This was an art practised, we are told, by the ancient Egyptians. We know, by experience on our seacoast, how effectively a mass of brush, filled with sand, has resisted storms, which played havoc with heavy masses of concrete, as illustrated at Atlantic City a few years ago.

It may become a problem how to secure large quantities of cheap ma-

terial, if sundry projects, seriously proposed, should attain a more definite stage. Amongst others, a dam at the straits of Belle Isle, and connecting Labrador with Newfoundland, has been considered, the object being to deflect the arctic current oceanward. This work, if ever consummated, might profoundly modify the climate of the British maritime provinces as well as our New England coast.

MR. SCHERMERHORN.—The use of brush in sea waters would be impracticable unless the brush was sunk in the sand so that the sea worm could not destroy it. In waters south of Boston it could not be used. Brush placed in the base of a breakwater, where the water was 30 to 40 feet deep would be so compressed by the weight of the superimposed stone that it would be a question, so far as volumes are concerned, whether the brush, no matter what the price paid for it, would not still be more expensive than stone. Beyond the districts in which the stone can be easily and cheaply obtained, artificial stone, or concrete blocks will be next in cheapness.

EDGAR MARBURG.—I wish to ask Mr. Schermerhorn whether any experiments have been made with a view to determining how the impact of waves is influenced by variations in the size and form of the resisting surfaces. I remember that some years ago, in connection with the design of the Diamond Shoals lighthouse off Cape Hatteras, a discussion as to the relative effect of the wave forces on plane and cylindrical surfaces showed great differences of opinion.

Again, is it the usual Government practice, in inviting bids on subaqueous constructions, to furnish data as to depths, etc., which are not guaranteed, but which the bidder must either accept at his own risk or verify at his own expense? I remember that, in the case of the lighthouse just referred to, the contractor found the conditions at the site radically different from those indicated on the maps previously furnished him as a basis for his bid, and that he had afterwards no redress in the matter.

I wish to inquire further, whether, in the case of masonry exposed to wave action, it does not sometimes happen that stones on the side of the open sea are forced outward as the result of unbalanced air pressure due to the formation of a partial vacuum by the retreating wave?

MR. SCHERMERHORN.—As to the data furnished in specifications the rule is almost invariably this: The attention of the bidder is called to the fact that he must verify all data, and I do not think that any responsibility is assumed by the Government for defective information. They furnish the most recent surveys, and such physical data as the office can supply, but the contractor must assure himself as to its reliability. As to the character of the data furnished to bidders at Cape Hatteras it was

a matter of comment that the surveys were perhaps ten or twelve years old. At all events there was more water on the site of the proposed light-house than the surveys showed, and there was no opportunity to get the foundation down in this deeper water before a storm swept it away.

As to the impulsive force of wave action I do not think there are many data beyond the experiments of Stevenson on that subject. Engineers nowadays would not value abstract calculations very much. I think they would rely more on experience. In fact the whole question is an obscure one. What shall we say of this force which presses back the dynamometer 6,000 pounds? Does it mean that the wave struck with a force that asserted an absolute push of 6,000 pounds? I must confess that I do not accept that view. At best it is only a measure of the comparative forces of waves at different points. At Oswego most confusing results were obtained. A storm would pass over the dynamometers from which one might expect a register of 2,000 or 3,000 pounds. In some such cases they did not register 20 pounds. In other cases where the waves were not as high, records of larger pressure were obtained. My conclusions were that the wave-force was confined to a very limited depth. Referring to the removal of stones from a sea wall by wave action I witnessed this force in a marked way. At Oswego a sea wall had been built. It was of hammer faced granite with close joints, and the stone not only with dressed faces but with upper and lower and end joints thoroughly dressed. The wall was exposed to the sea at every gale. The stone which was removed was about 5 feet in length and 2 feet in height. It had a superficial face of about 10 square feet. When I first noticed the stone it was withdrawn from the wall one-half inch, and later 1¼ inches. The stone was finally entirely withdrawn from the wall. The only explanation I can offer is this: the vertical joint at one end was defective through the mortar being washed out. As the sea beat against the wall the water was driven into this narrow joint and finding a vacancy at the back of the stone, the stone was pushed out by hydraulic pressure. It was not an infrequent case for the stones to be bodily thrown entirely off such structures. Very great care must be taken with joints where masonry breakwater superstructure is used. In some types of breakwaters immense blocks of concrete have been used. The blocks are laid upon the sloping system with tongues and grooves which joint them together. It is necessary to guard against air spaces, however, for if such spaces are left in the work the waves driving in upon air spaces would impress themselves upon all the air spaces in the vicinity and possibly result in forcing the stone out of place.

Mr. Christie.—Did those large blocks of concrete of which you speak form the upper work at Wick Bay breakwater?

MR. SCHERMERHORN.—The special stone to which I referred was at the end of the breakwater. Breakwater ends are exposed to very much greater force than the other parts of the work.

WALTER L. WEBB.—Can you remember the figures in regard to the movement of the breakwater at Oswego? I remember some calculations made as to the force required to move it.

MR. SCHERMERHORN.—That was an interesting case, but its details have passed from my memory, beyond the fact that a part of the timber and stone breakwater was bodily moved upon its base by the action of the waves; this displacement covered several hundred linear feet of the breakwater.

PROF. WEBB.—The particular point of failure to which I was referring was that a portion of that crib was driven in several feet.

MR. SCHERMERHORN.—In the case to which you refer cribs 40 feet deep and 30 feet wide were pushed bodily in by the sea a foot or two from their original position. They are probably in that condition to-day.

XIII.

SOME FEATURES OF STONE ROAD CONSTRUCTION.

By Benjamin Franklin, Active Member.

Read November 6, 1897.

The subject of road construction has been so thoroughly ventilated during the past few years, and has shown such rapid improvement in method and result, that the writer approaches it with great hesitation.

From his own experience covering a territory largely diversified in conditions and soil, he has found conflicting theories and practices among both scientific and "practical" men, and it is more with a view to inviting discussion on a few points, rather than advocating special practice that this paper has been prepared.

Where private parties and corporations are not concerned, the construction of a road, aside from the absolutely necessary features and details, is influenced by the amount of money available and by political conditions. It is a debatable question which of these two is the more important, since "politics" frequently controls specifications and superintendence, making necessary an extreme degree of tact and firmness on the part of the engineer in dealing with contractors and public officials, whose selfish interests are at variance with thorough work.

The points of this subject which will be discussed are: (1) The use of clay or loam as a "binder" on stone roads; (2) The thickness of stone roads; (3) The comparative merits of Macadam and Telford roads.

The specifications of the state of New Jersey, the city of Philadelphia and of many townships and municipalities of both this and the neighboring states permit the use of clay, gravel and loam for binding purposes. It is also stated that French engineers use in their stone-road specifications, clay, varying in proportion from 6 to 20 per cent.; and the practice among our own engineers and contractors is so general that even with the insertion of a prohibitory clause in the specifications it is diffi-

cult to prevent its use. As a binder, clay possesses two prominent disadvantages: it is a lubricant, reducing friction between stones, and it also absorbs a large percentage of moisture, changing in bulk and consistency under varying conditions of weather and temperature.

Used as a surface binder, as the Philadelphia specifications permit, it quickly makes a road muddy after a storm, causing ruts in spring and dust in summer.

Macadam so thoroughly understood these disadvantages, that he declared he would have no more clay or loam on his work than a mason would have in his mortar, claiming that it made the road more pervious to water.

From a contractor's standpoint, however, the use of clay or loam is an excellent practice. It "packs" well and quickly and saves rolling, giving to a road when first built a smoothness and finish at comparatively slight cost.

Again it is a very good adulterant, and this, the writer believes, constitutes one of the most important objections to its use. Every cubic foot of foreign material used on a road means a saving of good pure stone or metal which should go there, and which would always present a uniform homogeneous surface to wear. It is barely possible that a little might not be objectionable, but the tendency of the contractor is to use it with great freedom of judgment.

We believe that with its use, a road rapidly deteriorates, has a tendency to rut, is more easily affected by frost, and in wet seasons absorbs moisture, which by percolating to the foundation, makes this more unstable.

The use of unassorted stone, not too large or hard, and with a sufficient amount of chips and screenings to fill voids, and with proper wetting and rolling during construction, will, we claim, give a firm, solid road, and one that will be drier in wet weather, wear longer, and give more satisfaction in all seasons than any in which foreign material has been used.

In the early days of stone-road building a thickness of 20 inches or 2 feet was considered necessary for ordinary travel. Experience afterwards reduced this to 12 or 15 inches.

At present, with the use of heavy steam-rollers, excellent and

economical roads of only 6 or 8 inches can be built upon well-drained earth foundations,—although the majority of engineers and contractors still advise the greater depth.

It seems, however, to be a question of wise economy, for it has been proved that upon a bed of proper character, a core of coarse sand or fine gravel will be mechanically as serviceable as the most costly stone foundation. A core made of materials of this character, when covered with a layer of thoroughly compacted stone of only 4 or 6 inches thick, will form a firmer and more lasting surface than a much greater thickness of stone road laid in the ordinary manner.

If then it can be shown by experience that with proper construction, light stone roads give excellent practical results, what is the use of burying several inches of good stone in unnecessary foundation and retarding through ignorant extravagance, road development and improvement?

According to the report of the County engineer embodied in the State Commissioner's report there are at present 106 miles of 4 and 6 inch stone-roads in Passaic County, N. J., which were never in better condition than at present.

In Morris and Essex counties of the same State, and also in Connecticut, chiefly near Bridgeport, there have been built a number of roads of a similar character which show favorable records.

In localities in which stone is plenty and can be economically handled and prepared, it is probably the cheapest material for use in foundations. Where however both the bottom-stone and metaling are difficult to procure, to reduce the cost of road improvement so as to obtain the greatest practical good from limited appropriations becomes a nice problem.

The first requisite is good drainage, both for the surface and foundation of the road. Beyond this the essentials are a surface that will hold compactly together and will not break through under heavy loads; a metal of the quality offering the best resistance to wear; and a bed shaped to correspond with the desired surface.

In stiff clay soils, first-class road foundation can be made when coarse sand or fine gravel can be economically obtained by excavating the roadbed to a depth of not less than 5 or 6 inches

below the sub-grade and filling in with this material thoroughly compacted and rolled. In localities where these materials are not at hand, good results can be obtained by laying a light stone covering on a bed underdrained by tile laid parallel with the axis of the road, and at a depth regulated by its width, care being taken that the filling in over the tile be done with porous materials, that the cross drains are properly placed and that the side gutters are not neglected.

About two years ago the writer was requested to draw up specifications and superintend the building of a 4 inch stone road, on a clay soil of such a character that in wet weather he had frequently seen lightly loaded carts and wagons mired in it. Yet the road has very successfully passed through a winter under extremely trying conditions, and bears very favorable comparison with a 10 inch road in the same neighborhood only a few months old—a fact which he deems due wholly to the use of sand for a foundation, and the absence of clay as a binder.

Sandy districts possess natural advantages, and if proper attention be given to the side gutters, and the sandy bed confined, the very best results will here be obtained from light stone roads.

In the writer's opinion the best road foundation is clean coarse sand, as it not only changes its bulk least under extreme conditions of moisture and temperature, but it acts as a cushion for the metal covering, making its surface more elastic and less liable to rut.

Generally, in localities in which this character of soil is found, road stone of any kind is difficult to obtain; and it is here one would expect to find the art of light road building carried to perfection, but it is an anomalous condition that as yet we have not been able to discover in any such locality a 4 or 6 inch road more than three years old.

The writer knows that 3 inches of well-rolled macadam on a sandy bottom will resist, without breaking through, the pressure of a narrow tire wagon, weighing with its load not less than five tons.

In the matter of good roads, New Jersey is one of the most progressive States in the Union. During the past six years it expended over $1,500,000 for that purpose upon a total of 300

miles. Quoting from the report of its State Commissioner of Public Roads (Mr. Henry I. Budd) for 1896:

"Experience has taught that a traffic-worn macadam road will stand up when only 3 or 4 inches thick. It is therefore demonstrated that when good economy is necessary, 4 to 10 inches is sufficient according to location and foundation."

Mr. James B. Orcutt, discussing this matter in his "Move for Better Roads," maintains that a layer of clean sand or gravel is better and frequently cheaper than a foundation of stone.

In order to obtain expert information on this branch of the subject, inquiries have been addressed to Mr. William L. Whitmore, Engineer of Passaic County, N. J., whose district covers over 100 miles of 4 and 6 inch roads, who has courteously furnished the following replies:

(1) What is the character of the sub-soil in Passaic County, on which 4 and 6 inch roads are built? "Clay and sand."

(2) Do you make a special foundation of sand or gravel? "No. The sub-soil is shaped to conform to the finished roadway, and thoroughly rolled with a three-ton roller."

(3) What is the character of the traffic? "Our roads are subjected to all kinds of vehicles, from heavy trucks to light road wagons. A great many of our streets are paved with 4 inch macadam only."

(4) What is the quality of the stone used? "Trap rock. (Bergen Hill?)"

(5) Do 4 inch roads require more annual repair or need special watching at critical seasons? "Unless destroyed by freshets or washouts, 4 inch macadam roads will stand three years without repairing."

(6) What is the oldest 4 inch road in your district? What repairs has it had? "We built our first macadam road in 1888, no repairs were made to it except in a few places until this year (1896), when we top-dressed it with 2 inches of 1½ inch broken stone, clay and ¾-inch screenings."

(7) Do not these roads frequently break through under moderately heavy travel? "Not if they are properly constructed."

There are two points in Mr. Whitmore's practice to which the writer, from his own experience, takes exception. The first is

the neglect to specially prepare the roadbed beyond shaping and leveling. Where the soils are such as are affected by frost and moisture, a foundation layer of sand and gravel would obviate all evil effect.

Again, the argument advanced against the use of clay as a binder on heavy roads, holds with much greater force when the roads are but half the customary thickness.

Some time ago the writer was directed to build a road for a cemetery in one of the interior towns of Pennsylvania, the depth of 18 inches being insisted upon by the management, because something substantial was wanted. The grades were heavy, but the drainage was well cared for by silt basins placed at short intervals. Almost immediately after its completion a commission was received to draw up specifications for the construction of a road for another cemetery nearer home, where the conditions of soil were the same. The road as built was 8 inches in depth; the metaling selected trap rock, and in spite of the efforts and protests of the contractor, no clay was permitted to be used. The first road cost about $1.00 per yard, and the other 56 cents. Early in the following spring the writer personally inspected the latter road, and although the frost was leaving the ground and a very heavy rain had fallen on the preceding day, he found the road in perfect condition, and walked its entire length dry shod. The superintendent stated that he had just returned from a drive through several other cemeteries, and found his own roads the best among those he had examined. As all the roads were drained in a similar manner it seems evident that the superiority was due to the absence of clay as a filler and binder, which illustrates the first claim in road building. In closing the exposition of this branch of the subject it is suggested that the specifications for light stone roads be drawn up to cover the following: The roadbed should be properly shaped, made of the proper materials, well drained, and thoroughly compacted by rolling before any metal is applied. Use metaling composed of coarse and fine stones, proportioned to fill all voids.

Use clean binding, if possible, hard as the metal itself, in place of either filling or lubricating material. Use a steam roller about 10 tons in weight, and roll until water flushes on the surface.

We come now to the last division of the subject. When localities within easy reach of the best engineering talent still build alternate sections of Telford and Macadam roads for the purpose of determining by actual use the superior qualities of either, it is clear that either their comparative merits have not been fully proven, or if they have, the knowledge has not yet been generally disseminated. In cost the two systems vary but little, possibly a slight difference in favor of the Macadam, but while in general practice more of Telford roads are built, scientific thought and experience seem to incline more towards the Macadam as being the better system.

One thing should be borne in mind in making a comparison. Generally the roads that are built in the suburbs and country districts are under the control of men, more politicians than engineers. What is needed therefore is someting that will wear as long as possible under this system, which encourages carelessness, neglect, and ignorant superintendence.

As far as the writer can ascertain, the average wear of a metal surface under ordinary traffic is $\frac{3}{4}$ inch per year.

On a Telford road after the metaling has worn away somewhat, the rate of wear increases rapidly over the first year, because the foundation stones appear as boulders, and acting as anvils, rapidly pulverize and destroy the metal.

Again, the interstices of the foundations on a Telford road, even if carefully filled in with chips, show a very large percentage of voids, giving free access to water, which, reaching the natural soil below, under the action of frost, upheaves the bottom stones, and destroys the coherency of the structure, allowing the metaling to settle to the bottom.

The common practice in the construction of a Telford road is to use a very inferior quality of stone for the foundation, and as it seems to be the rule to resurface the roads only after the bottom boulders make their appearance, these, under the action of traffic and weather, quickly disintegrate and give rise to hollows and ruts.

As the Telford foundations are inelastic and unyielding, the upper or metallic surface wears out more quickly on that account.

On the other hand a well-built Macadam road will wear without renewal until within 3 or 4 inches of the bottom.

One further advantage in favor of the Macadam is that with the rapid growth and development of our suburbs, we are often compelled to disturb a road to lay or repair water and sewer pipes, and satisfactory reconstruction of a Telford foundation is very difficult.

Apparently the chief advantage claimed for a Telford road is its foundation. But in this it can claim no superiority over a well-drained bed, which after all is the vital essential of a good road of any character.

If the subject and time permitted, the writer would like to dwell upon the road-laws of the various States, particularly that faulty feature which enables the farmer to "work out" his road taxes.

He would also like to touch upon the proposition to employ convict labor upon State and County roads. He feels, however, that he cannot close this subject without paying a tribute to the L. A. W., which by united intelligent and persistent effort has accomplished so much during the past few years in the direction of good roads and first-class streets.

DISCUSSION.

THOMAS G. JANVIER.—This is a very interesting subject to me. I have been engaged in it for about twenty years. I wish to speak about one point particularly, about the clay binder. I must differ a little from the author of the paper in that matter. From practical experience I find the clay binder, if properly put on, makes a better road. I know of one case in Delaware county. We built a road in 1888 with Telford foundation, and 4 inches of broken stone on top. On the 4 inches of stone we put a light sprinkling of clay, rolled it thoroughly and then applied about 1 inch of coarse screenings which was thoroughly sprinkled and rolled until the surface became hard and smooth. Nothing was done to that road until this year. It lasted about nine years. It was in good condition with the exception of the surface which was worn down very much. There was hardly a rut to be found in the road. The wear of the road was very even, scarcely a rut to be found in it. I think where the clay is properly applied it is certainly a great advantage, and my practice has proved it so without a doubt. This year we applied an average of about 3 inches

of ¾ stone on top of that old surface which was as hard as iron. We could have picked it up, but that would have been too expensive, so I prepared specifications to cover it with ¾ inch stone, 2 inches at side and 4 inches at center to increase the crown a little. On the top of that we applied a light coat of stone dust so as to put the road in good condition for wheelmen. I believe if ¾ inch is applied and allowed to pack by the travel it makes a better road and is not so apt to rut as when you put on screenings. Many wheelmen like a smooth road at once and this you cannot get with ¾ inch. We tried to bind the ¾ inch by rolling, but could not. We then applied a light coat of clay, a very light coat. I would emphasize this. We used just enough to make the two sizes bind. We applied this to the ¾ inch stone, then covered with ½ to ¾ inch of stone-dust, not screenings, as they generally rank ¾ inch, but pure stone-dust almost like flour. We rolled it thoroughly and the road was in an elegant condition when completed. To-day you can go over that road an hour or two hours after the hardest rain and you will not soil your shoes; and you can wheel over it in less time. That road has two coats of clay, one at the foundation; and this spring when we resurfaced it had this clay on top of the ¾ inch. In all roads in Delaware county clay has been applied, but where not applied judiciously it injures a road. With proper supervision there is no reason why it should not be applied. It should not be put on in lumps. Contractors have to be watched pretty closely. I might say in regard to the road mentioned that it is the Darby and Radnor road extending from Darby through Lansdowne to Bryn Mawr and Wayne. When that road was being constructed the contractor was not there himself and his foreman was careless and allowed the men to put the stone in as they pleased. Instead of breaking joints as far as possible they made joints on the line of the road which would make a rut at once, but that was stopped. With proper supervision a Telford road 8 inches foundation with 4 inches of broken stone on top, rolled and with a light coat of clay, then screenings and dust, will be a first class road. I speak from an experience of twenty years. The clay must be applied judiciously. In regard to Macadam and Telford roads I must say the latter is superior to the former. I made experiments to satisfy myself as to which is the best. Comparing on similar soil I found that a Macadam road of the same depth as a Telford road rutted much more quickly than the Telford, especially if the subsoil had a tendency to become damp. Occasionally, no matter how well the road is built the dampness will work under it. I found a Telford road more durable and that it would not rut as soon as Macadam. I attribute it to the resistance given by the large stones in the foundation, thus preventing them being forced into the clay roadbed by the heavy pressure of travel.

THE PRESIDENT.—Where was the road in Delaware county?

MR. JANVIER.—It extends from Lansdowne station to Marshall road in Delaware county, running north from Baltimore Avenue. I hesitated a little about putting ¾ inch stone on that hard surface—it was hard as iron, it could not have been otherwise after nine years' wear. It was not worn down to the foundation stone. If the top stone is the proper kind and the foundation is properly laid, it will not wear down to the foundation stone for a long time. Here and there one might find the foundation stones sticking up, but it was not down to the general foundation. It was so hard that I hesitated to apply the ¾ inch for fear it would not bind, but I risked it and to-day it is one of the best roads in the county. To one other point I would like to call attention, especially with new roads, and that is sprinkling. A new road, no matter how well made, unless kept sprinkled for two, three or four months, will be apt to bake, then break up and go to pieces. When this road above noted was resurfaced I wrote to Councils requesting that it be sprinkled for some time, which was done, and it is now in as good condition as when finished. It is as smooth as this floor and hard as iron, a perfect road. I have been over a great many roads on my wheel and I have yet to find a road equal to it. I attribute to a good road in the first place, perfect drainage and heavy rolling. We use a fifteen-ton roller, then a light coating of clay and top-dressing lightly put on. Under these conditions a road will last a long time with very little attention. There is the proof, nine years and nothing done to it, not a ton of material put on this road from 1888 to this spring. There was one portion, where it was shaded, that had to be coated once or twice, but from Baltimore pike to Marshall road it did not have a ton of stone on it from 1888 to this spring. It was a fairly good road, but we wanted it better. It would really have lasted two to three years longer from the condition of the surface.

THE PRESIDENT.—So it has been with engineers since the days of Macadam and Telford. I suppose there are defects in both principles, as engineers are so generally divided.

MR. JANVIER.—In regard to the stone I make my specifications thus: The foundation stone shall be hard, tough and durable. When I can get it, that is when the financial conditions allow it, I prefer trap rock for the broken stone. I find no trouble at all in the binding part. With this light coat of clay on the foundation and a light coat on the broken stone for a binder, we do not have any trouble. There has been no trouble with the clay working through the stone and cannot be any except where it has been improperly laid on. Regarding the lime stone, my experience has been a sad one. Several years ago, the late Philip J. Walsh was

supervisor of Delaware county and he put a good deal of limestone on the roads, and those of you who have travelled on the Baltimore pike during the last four or five years have had experience of the limestone; there was general complaint and growling from one end of the township to the other. In windy weather there would be a cloud of dust rolling into the houses and in wet weather the mud spoiled the paint on the carriages. Soft stone I have never used for top dressing, but we are decidedly opposed to limestone in Delaware county. This year we covered it with trap rock. It may be a different limestone from what is used in the western part of the State, but it made a very poor specimen of road. There is another point about which someone might wish information, and that is the cost of these roads. We are putting down some stone roads this year, first-class stone roads in every respect, good foundations, 8 inches with 4 inches of top dressing, trap rock, for 65 cents per square yard. The cost used to be 80 or 90 cents to $1.10.

MR. FRANKLIN.—This paper was written for the purpose of bringing out a discussion of this character. Regarding the merits of the Macadam and Telford roads I think if the drainage of the roadbeds were properly done the Macadam would wear better than the Telford. Regarding the use of clay as a binder my own experience is that it is impossible to keep the contractor from using too much. It is possible that a small quantity will do no harm and may do good, but 90 per cent. of the stone roads in which clay is used, soon commence to rut. I agree with Mr. Janvier fully regarding his experience with limestone. I have seen a new limestone road and it is just as he says. Regarding cost, you could build a good Telford road from 60 to 70c. per square yard, 10 inches in depth, even if the stone is not in the immediate vicinity.

THE PRESIDENT.—What would be the shape of your road? How much arch would you give it?

MR. FRANKLIN.—I use between 3 and 4 per cent. grade from crown to gutter. If I have a special quality of sand and gravel I wet it, otherwise the foundation could not be made uniform. In all roads I give the bed a rolling first.

MR. JANVIER.—Regarding that Telford and Macadam test I made, I wish to say that the subgrade had the same crown as finished grade. There was about 5 to 6 inches crown in the 18 feet both Macadam and Telford, and I found the Macadam road rutted very soon and the Telford did not, with the same travel on it. The soil was clay, but for some reason I could not tell why, the Macadam rutted, and as soon as the travel struck the Telford it was noticeably free from ruts, and the joining of the two quite apparent.

JAMES CHRISTIE.—The wide difference of opinion regarding the utility of limestone, may be accounted for by the various qualities of material termed limestone. We find large deposits of marine petrifaction, which yield excellent lime but poor building stone—other varieties poorer still are stratified with layers of calcareous shale which will not stand the weather, and as poor a material for top dressing of roads as could be found to produce abundance of dust or mud, as the weather dictated. On the other hand we have large deposits of the magnesian limestones, a dense, hard stone only inferior to trap rock. A similar distinction might be applied to clay, according to the method it is used; when well compacted, with only sufficient moisture to bind it, it remains a coherent impervious body; on the contrary, with too much water it shrinks and cracks, and it is probable this distinction largely accounts for the diverging views expressed regarding the value of clay for puddle walls.

MR. JANVIER.—The clay we use in Delaware county we tried to get as pure as possible, free from any foreign substance, the best clay we could get.

MR. FRANKLIN.—I do not think that vitrified brick would answer for the track way, but it makes a capital gutter. It is scarcely durable enough for track way. Regarding the question of track ways, I believe there are sample stone roads with steel tracks built at New Brunswick, N. J., and at Geneva, N. Y. I wrote for information in regard to them and was told that the specifications were not yet printed.

MR. JANVIER.—Another interesting feature I observed this summer. We had to regrade an old stone road in Lansdowne which had been down for ten to fifteen years, and which had been covered with this limestone about four or five years ago. There were so many ruts in it that it was almost impassable. On taking it up we found nothing but macadam, the depth varying from five to six inches in some places and twelve to fifteen inches in others. In some places large stones were piled in indiscriminately. These ruts extended over the road from side to side. We repaired some portions of this road with trap rock and by this means hope to get better results.

WALTER L. WEBB.—The discussion of the relative value of Macadam and Telford roads will probably keep up as long as there are differences of opinion among engineers as to the minor details of construction, as long as there is variation (and there always must be) in the materials employed, and as long as there are differences in the fidelity with which the work is executed. If a road is carefully and honestly built, with good materials and with specifications suited to the materials, it will

be a good road whether it be a Telford or a Macadam road, and will be much better than a road built on the other system, which is carelessly or dishonestly constructed or which is made with unsuitable material, or according to unsuitable specifications. As such defects generally exist to some extent, the comparison of the wearing qualities of two selected roads is practically valueless unless the minute details of the construction of each are known. There is, therefore, no end to these discussions nor hope of the discussions leading to a definite conclusion in favor of either system.

THE PRESIDENT.—I think that has been the opinion of engineers for a long time back. Still I would like to hear from some one on the Macadam side. It seems to go the Telford way this evening, and if there is any one present who is a strong advocate of Macadam and can tell its good points over the Telford I shall be glad to hear from him. I think there are improved roads built in Montgomery County under Mr. Cassatt's supervision, but I do not know that there is any one here who had anything to do with the construction of them. Those roads were built well and I believe have given great satisfaction for a number of years.

LOUIS Y. SCHERMERHORN.—Telford and Macadam roads of to-day differ very materially from the early Telford and Macadam roads. The Telford road was originally about 14 inches deep, of which 7 inches was a sub-foundation of stone blocks and the remaining 7 inches a broken stone surface upon that foundation. The blocks were carefully placed and the interstices were filled by stone chips driven in between the openings and the whole driven down to a comparatively uniform surface. On the top of this foundation was placed broken stone of two grades. The coarser grade npon the paved sub-base and the finer upon the surface: the finer stone consisted generally of flints. The Macadam road had the same depth of 12 or 14 inches. The lower half was composed of stone two to three inches cube, with carefully prepared stone for the surface. For this final surface the hardest attainable material was used, broken to a very uniform size, for which the specifications did not allow any stone to be used which weighed more than 6 ounces; and upon roads built after the approved Macadam plan the final surface consisted of still finer material. We knew nothing of road construction at that time. Thirty-five years ago when the roads in Central Park were built they were called Telford and Macadam roads. The Telford roads were to stand the heaviest traffic. The Macadam roads were to bear the lighter traffic, but they were not essentially Telford or Macadam roads. On the Telford roads the foundation course was spread quite carefully into a surface approximately even with the bottom, but no effort was made to lay these

stones regularly, they were simply dumped in and raked over until approximately formed into the proposed section of the road. On top of that was placed the finer broken stone and gravel. I have never known of strictly Telford roads having been built in this country. The gravel used upon these roads cost about $2 per yard; it was of excellent quality and the best to be obtained. In my Western experience we had nothing but limestone. It was very hard, with a glassy fracture. We used gravel for surfacing which was also essentially limestone. I quite recently saw some of those roads made over thirty years ago and found them in excellent condition. They had been surfaced at intervals of perhaps six to eight years, and I saw no indication of the road surfaces breaking through or rutting. Regarding clay as a binder, we have no exact definition as to what it is, but I think that the clay which is used as a binder has more or less loam and earthen material mixed with it. I have tried the experiment of rolling broken stone with a steam roller, without surfacing material until all the crown was rolled out, and the broken stone, which was originally sharp and angular, became thoroughly rounded. Under the old system of making roads the stone was broken by men upon the roads and the rolling was done mainly by the traffic of the road; and the final surface of such roads was obtained by the united action of wheels and the clayey material brought upon the road surface. If all outside material had been excluded from the surface, I think the ruts would have worn themselves through to broken stone, while the stone would have become more or less rounded. Whether it is screenings, gravel, or clay, I think it amounts to one and the same thing. The action of the roller and the wear of carriages reduces the surfacing material to a compact condition which, while not clay, is the necessary material to give coherency and strength to the surface. I think it makes but little difference whether it is gravel, screenings, or clay, so long as the material used gives a top surface which will absolutely prevent water from percolating through. Drainage is absolutely necessary and it would be better to economize on stone and expend more money on drainage than to sacrifice drainage for increased depth of stone.

Now as far as depth of stone is concerned I think the point Mr. Furber alluded to will bear further illustration; the stresses impressed upon the road surface do not pass vertically downward to the foundation, from the fact that as the stress is carried downward, the fragmentary stones which make the depth of the road, divert it from a vertical to an oblique direction. Now the greater the depth of stone, the wider will be the triangle formed by the limiting lines of the stress, and if the road material is only 4 inches deep the internal stress is carried down so that at the base of the

roadbed it may cover a width of only a few inches, and the load impressed upon that surface may be sufficient to cause the roadbed to sink. The depth of material is a question which relates to the initial loads which are to be brought upon the road itself. Roads in parks and cemeteries would be subject to very light weights indeed, and I should assume that a road 18 inches deep, such as has been mentioned, would be an extravagant outlay of stone for a road of that kind. If roads are to be subject to heavy weights and perhaps inadequate repairs they certainly require to be very much heavier than roads subject to the wear and tear of lighter traffic.

MR. JANVIER.—Mr. Schermerhorn made an insinuation which I cannot stand. He says they do not build roads as they used to. In Delaware county we do. The roads are to be brought to sub grade one foot below the finished grade, with a crown of six inches from center to side. When there is a fill it is to be thoroughly rolled until hard, thereby getting the water off quickly while it is a green road. Then here are our specifications for laying the stone. The stone to be hard, tough and durable, eight inches to ten inches long, four inches to six inches wide, eight inches deep. To be laid by hand on broadest edges and lengthwise across the road in close contact, breaking joints as far as possible. The tops of stones to be broken off and the interstices to be filled in with stone chips, making this a firm, substantial, and even pavement. That is the way we do it in Delaware county. If that is not care in foundations I should like to know what is.

MR. SCHERMERHORN.—I had no knowledge of the roads described by Mr. Janvier, since they have come into existence since I have had to do with road building. The roads to which I referred were those of thirty years ago. The roads described by Mr. Janvier bear a close resemblance to standard English and Scotch roads.

MR. JANVIER.—Regarding the rolling, I may say that in my experience it is insisted that rolling be done from side to center all the time, up one side and down the other, rolling from sides to center. That keeps the crown up stiff right through the rolling and it never gets flat.

MR. FRANKLIN.—If the foundation of a road is sand and gravel it will stand almost anything. I built my first four-inch stone road under protest. Sand being almost non-compressible if confined, will make a splendid foundation, as good as if solid stone were used.

THE PRESIDENT.—Mr. Franklin makes a good point in regard to sand. If Mr. Janvier could get it out in Delaware county he would no doubt be in favor of using it. Do they place the stones by hand?

MR. JANVIER.—All by hand, just as you lay Belgian block, and if it

is not done right we discharge the men and get men that will do it right. If the contractor does not attend to his duty we discharge him.

HENRY LEFFMANN.—I do not desire to convert the Club into an antiquarian society, but I thought it might be worth while to take a few minutes to show some slides exhibiting the method of road construction employed by the Romans. The views that I will show are taken from A. Leger's work, *Les Travaux Publics, etc., aux Temps des Romains.*

The Romans constructed their main roads to last forever. They are true monuments, made of siliceous and calcareous materials far superior to the highest type of modern work. The superstructure was a roadway, generally very strongly convex, and two side-paths or footways. Near Rome, the full width was often twenty meters, but not usually. From three to three and one-half meters for the smaller roads and from four to four and three-quarters meters for the larger, are dimensions that have been generally noted. In mountain regions, the road was narrowed to a single carriage way, one and three-quarters meters. The sidewalks were large near the cities but reduced to six-tenths meters in the outer districts. These were built of cut stone, at least on the border. At every twelve paces (18 meters), mounting stones were placed. At every thousand paces (1481 meters), mile-stones were erected. In one instance, the roadway was divided by a low wall down the middle, as if to surely establish two streams of traffic.

In the construction of the wagon-road a ditch was dug to the solid earth, which was stamped or rolled, or even stakes driven if necessary, then on a floor of sand, ten or fifteen centimeters thick, a layer of mortar was placed, after which they placed successively four layers, as follows:

Statumen. The support or foundation. A course of several layers of flat stones, bound by a hard cement, or failing in that, clay. This layer was usually thirty centimeters thick, and twice that in bad lands.

Rudus. A concrete of pebbles, stones or broken bricks, strongly stamped together with iron-sheathed stampers. This layer, when finished, was usually twenty-five centimeters thick. When mortar was lacking loam was used.

Nucleus. A layer of thirty to fifty centimeters of gravel or coarse sand, finer than the third layer, and rolled successively in small layers.

Summum dorsum (summa crusta). An convex layer twenty to thirty centimeters thick or more, made somewhat differently according to the materials at hand. It was either paved with cut stone or laid with pebble and granite, or metaled.

Some of the best roads were paved with marble. The minor or secondary roads were not so carefully made.

[Slides illustrative of these constructions were shown.]

ALLEN J. FULLER.—Nothing has been said as to keeping these roads in repair. It seems to me they need constant attention. They must wear out in a short time. What is the proper method for keeping them in good order?

MR. JANVIER.—The question of repairs is a disputed one. The best method is constant attention. Have small deposits of broken stone at different points along the road, and have a man to make repairs. The moment a depression or rut is formed, put on a small amount of the broken stone and the travel will pack it down. The road I mentioned stood eight years without repairs. The best practice is to have your deposits along the roadway. The trouble is that a penny-wise and pound-foolish policy is adopted and a road is allowed to go so long that repairs become expensive. The best roads have proven that constant daily attention is the cheapest in repairing. Have a man for every few miles of road and directly he notices a depression have him make application of broken stone to the place. The judicious use of the watering cart will add materially to the life of a road.

THE PRESIDENT.—When those repairs are made I suppose you put the roller over them or ram the stone down.

MR. JANVIER.—On general repairs, yes, but on patches the travel will pack the stone in a short time.

MR. FULLER.—Regarding the use of soft limestone, I have heard of oyster shells being used. It is not common to use them in this part of the country, but in the South most of the good roads are built of oyster shells, and some of the finest surfaced roads I have ever seen have been made with them. The roads are very readily repaired. A wagon comes along filled with shells and a bushel or so is shovelled off at a time, and in a few days the surface is as good as ever.

H. V. B. OSBOURN.—I had occasion to note stone tracks on the old Albany post road just this side of the Adirondack mountains, over which probably the old heavy carrying wagons have passed for many years. In some cases the stones are worn down about three inches. They were simply two parallel flags probably eighteen inches in width and three inches in depth. Judging by the country and condition these flags must have been down for a great many years. That follows a little bit after the old Roman roads, or rather the way of making them. As regards oyster shell roads, I have noticed them in Maryland as being very good, especially in wet weather.

MR. CHRISTIE.—At the upper end of Washington street, in Manayunk, can be seen a stretch of highway paved with oyster shells. There is heavy

hauling on the road, which has been paved for several years, and retains a good hard surface. They are apparently cemented together and are quite hard.

Mr. Fuller.—We have a road of that description in our fourth district yard, Twenty-sixth and Master streets, which is constructed in the form of a parallelogram, and with a number of intermediate lanes extending from side to side of the square.

The main road and lanes were built by excavating from six to twelve inches in depth and filling in the space with oyster shells, which were dumped from the cart, and only required leveling on the surface to prepare the streets for use. Additional filling was required, however, as the shells were broken and packed by the heavy hauling.

These roads now present a hard and compact surface, and notwithstanding the more than ordinary wear to which they are subjected, very little repairing is needed.

E. M. Nicholls.—I think this discussion has brought out the fact that durability of the work depends largely on compacting the materials. The principle that Mr. Schermerhorn brought out is that the load is carried on a widened base at the foundations. A Macadam road can be built and let go down by traffic and will yield a fair road after quite a time, but if it is rolled so that the stone is almost a solid mass, it will stand just as well with eight or ten inches as though you had eighteen to twenty inches. In making Telford foundation, unless it is thoroughly done so that one stone may distribute part of its load to another, I cannot see how it would be as efficient as the same depth of Macadam if properly compacted.

Wilfred Lewis.—Has any conclusion been reached as to the limit of tire that could be applied to the inch of width?

Mr. Janvier.—I think it is better that all heavy loads should be on tires not less than 4 inches. It is better for the road and better for traction power. That is, for heavy loads.

Mr. Franklin.—I think there are townships in some States that make reductions of taxes proportionate to the width of tires. Some road engineers think it well to make the rear axle a little longer than the other so that the wheels will not pass in the same rut. I think on roads where there are no rails or tracks you should have the bearing surface spread a little. The presumption is that the wagon's track will not wear a narrow rut.

The President.—In some publications I have seen some roads built with metal tracks for wheels.

Mr. Franklin.—I think I mentioned that roads of that nature were built in New Brunswick and Geneva.

WM. COPELAND FURBER.—(*Communicated Discussion.*) The essentials of a good road are simply expressed—*first*, a firm, unyielding foundation; *second*, a hard, durable, wearing surface. Without the first condition the second is impossible.

The character of the soil or substratum of earth underlying the road, will determine the character of the foundation. Earths have a "bearing resistance" which varies with the materials composing it, which materials are also affected by the presence or absence of water. The "bearing resistance" may be defined as the resistance which a given unit of surface offers to a given load before any displacement of material occurs. This "bearing resistance" will of course be much greater for materials such as rock, hard-pan and gravel, than for sand, loam or light soils. The correct proportioning of the foundation of a road, therefore, presents very much the same problem as the proportioning of the foundation of any fixed structure, in which the spread or area of the foundation is determined by safe resistance of the earth to displacement.

Upon the character of the earth underlying the road, and the weight of the vehicles and load, would therefore depend the relative usefulness and desirability of Telford or Macadam roads.

The Telford road, by reason of its selected foundation, insures that the loads which come upon its surface shall be distributed over a larger area of the underlying earth than the Macadam, which depends upon the accidental bonding of the broken stone to distribute its load or shearing force. A Telford road properly laid, made of the same amount and kind of material, therefore would be able to safely carry a greater load than the Macadam, or could be laid on softer or more yielding earths than the Macadam road.

The modern practice in paving is to regard the road as composed of two separate parts, viz.: foundation and wearing surface, which is exemplified in the concrete foundations used under vitrified brick, asphalt and stone block pavements in the best practice. The Romans seemed to understand the necessity of a sufficient foundation, and on the lantern illustrations Dr. Leffmann has shown us to-night the large foundation or footing-stones can be seen.

I would take issue with Mr. Franklin on the desirability of elasticity in the foundations of a road. Elasticity is not a desirable quality in a road, however much it may be in a vehicle. Any movement of the material forming the road rapidly destroys itself and its earth foundation.

Drainage is essential to all good roads, and is part of the foundation which need not be discussed here.

The wearing surface of a road is the second essential. In order to have

a good wearing surface the materials forming such surface should be of such sizes as will, when rammed or packed, form a volume free from voids. In order to insure this condition the sizes should be regularly graduated from the largest sizes to screenings, and sufficient clay or clayey gravel should be used to make a plastic "binder" to hold the materials, otherwise, there being no cementing materials, the broken rock will not become a compact mass.

If there be voids in the surface material of the road, vehicles will cause a movement of the stones, which rapidly destroys all cohesion, as well as permits wear on all sides of the stone, instead of only on its upper surface.

The clay binder performs another service, that of making the road "roof tight" or water-proof, causing it to shed the surface water instead of allowing it to percolate through the road material to its foundation.

Some limestones having a proper quantity of alumina in their composition, when ground up, make a sort of "natural cement" which might make the use of additional clay unnecessary with such stone.

The use of a harder material for the track ways of a stone road should, I think, receive greater attention at the hands of road builders. Vitrified brick, regularly broken squared blocks, etc., present a more durable and more even surface for the wheels than broken stone, which is rapidly ground to dust, after which it is useless. The United States Government is making some experiments with a steel track way made of an inverted channel which promises well.

In the South, particularly adjacent to the oyster regions, the roads are made of oyster shells, which make an excellent road with a good surface, and have the great advantage of being easily repaired. A man with a wagon load of oyster shells and a pitchfork can repair a considerable amount in a day.

XIV.

SOME PRACTICAL APPLICATIONS OF THE MASS CURVE IN EARTHWORK COMPUTATIONS.

BY WALTER L. WEBB, Active Member.

Read November 20, 1897.

BEFORE presenting the strictly technical portions of this paper, I wish to say a few words on the subject of the mass curve. As most of you know, it is a graphical device for the computation of earthwork. I do not know when or by whom it was invented, but I do know that the subject has not received the attention it deserves. There is not a published text-book, so far as I know, having an adequate treatment of the topic; the literature is confined almost exclusively to a few papers which have been published in the technical journals of the country, or have been published in the proceedings of technical societies; but in none of the papers has there been an adequate treatment of the subject, nor has there been any mention of some of the most valuable properties of this curve and the applications to be made of it. Possibly it is because some of the most valuable properties of the curve are generally unknown to the engineering profession that the subject has not received more attention than has been given to it. In order to make this paper consistent, it will be necessary for me to go rapidly over the fundamental features of the device and that portion will not, of course, be original with myself, except as to the method by which I develop the subject. In the latter part of the paper will be given some of the practical applications of the curve that I have never seen published and which are entirely my own.

When analyzing the cost of earthwork, the most variable item of cost is found to be that depending on the distance hauled. As it is manifestly impracticable to calculate the exact distance to which every individual cartload of earth has been moved, it becomes necessary to devise a means which will give at least an equivalent of the haulage of all the earth moved. Evidently the *average* haul for any mass of earth moved is equal to the distance

from the center of gravity of the excavation to the center of gravity of the embankment formed by the excavated material.

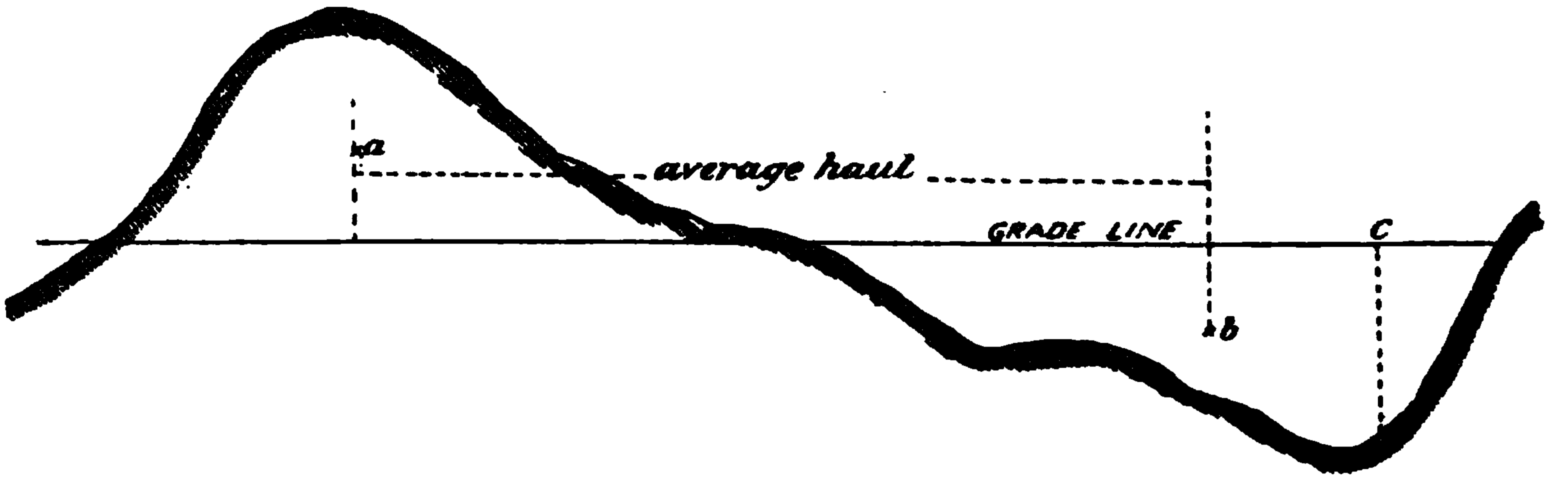


FIG. 1.—SIMPLE TYPICAL CASE, SHOWING AVERAGE HAUL.

Fig. 1 shows a simple typical case in which the cut on the left will be used up in forming the embankment on the right up to the point *c*. *a* is the position of the center of gravity of the cut and *b* that of the fill, and the horizontal distance between *a* and *b*

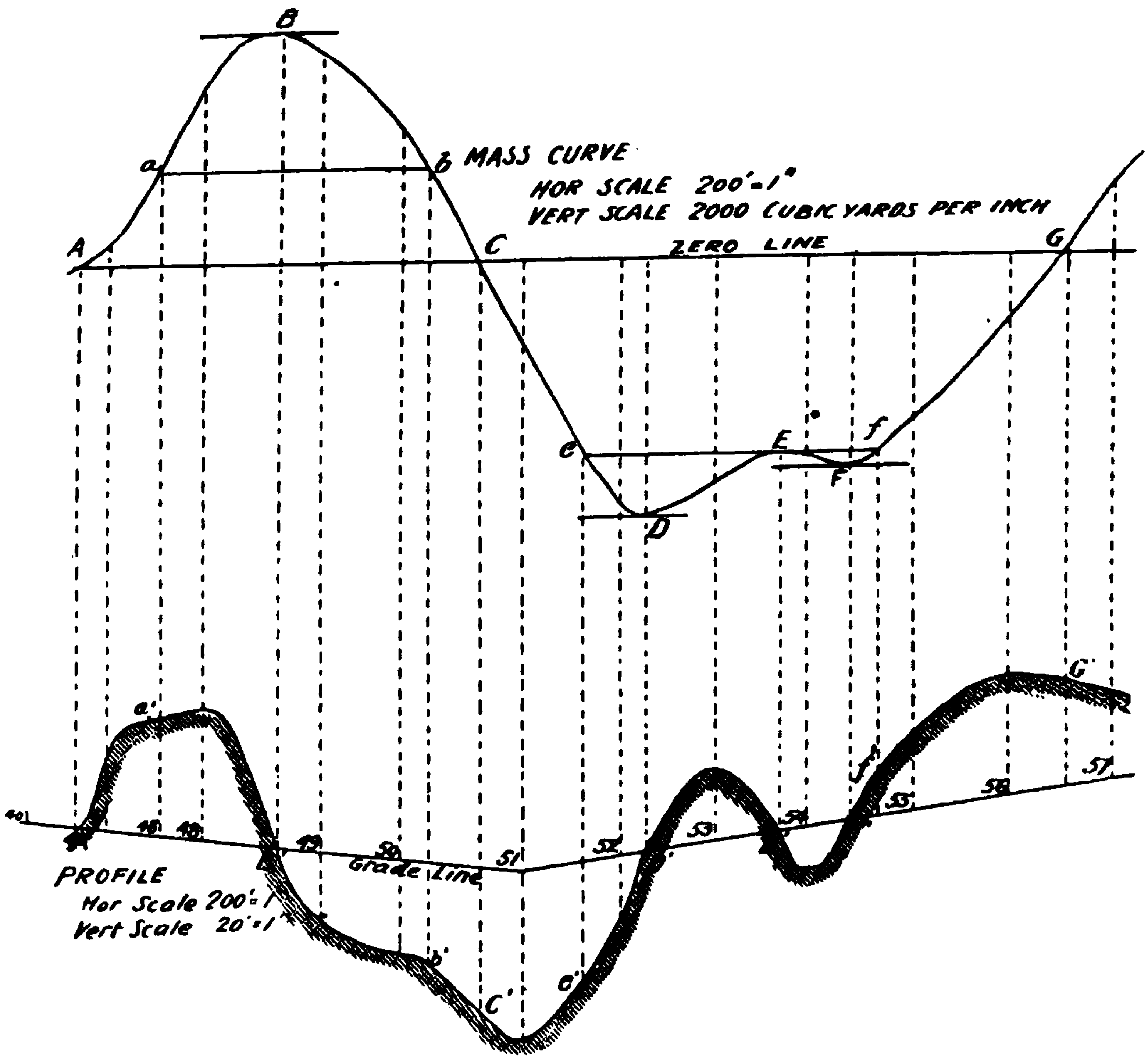


FIG. 2.—MASS CURVE AND PROFILE, TYPICAL CASE.

represents the *average haul.* As a rough approximation, the center of gravity of a cut (or fill) may sometimes be considered to coincide with the center of gravity of that part of the profile representing it, but the error is frequently very large. The center of gravity may be determined by various methods, but the method of the "mass curve" accomplishes the same ultimate purpose (the determination of the haul) with all sufficient accuracy, and also furnishes other valuable information.

In Fig. 2, let A' B' .... G' represent a profile and grade line drawn to the usual scales. Assume A' to be a point past which no earthwork will be hauled. Above every station point in the profile draw an ordinate which will represent to some scale the algebraic sum of the cubic yards of the cut and fill (calling cut + and fill —) from the point A' to the point considered. In doing this, shrinkage must be allowed for by considering how much embankment would actually be made by so many cubic yards of excavation of such material. For example it will be found that 1000 cubic yards of sand or gravel, measured in place, will make about 920 cubic yards of embankment; therefore all cuttings in sand or gravel should be discounted in about this proportion. Excavations in rock should be increased in the proper ratio. In short, all excavations should be valued according to the amount of *settled* embankment that could be made from them.

Sta.	Yards $\left\{\begin{matrix}\text{cut} + \\ \text{fill} -\end{matrix}\right.$	Material.	Shrinkage factor.	Yards, reduced for shrinkage.	Ordinate in mass curve.
46 + 70					0
47	+ 195	Clayey soil.	— 10 per cent.	+ 175	+ 175
48	+ 1792	" "	— 10 per cent.	+ 1613	+ 1788
+ 60	+ 614	" "	— 10 per cent.	+ 553	+ 2341
49	— 143			— 143	+ 2198
50	— 906			— 906	+ 1292
51	— 1985			— 1985	— 693
52	— 1721			— 1721	— 2414
+ 30	— 112			— 112	— 2526
53	+ 177	Hard rock.	+ 60 per cent.	+ 283	— 2243
+ 70	+ 180	" "	+ 60 per cent.	+ 289	— 1954
54	— 52			— 52	— 2006
+ 42	— 71			— 71	— 2077
55	+ 276	Clayey soil.	— 10 per cent.	+ 249	— 1828
56	+ 1242	" "	— 10 per cent.	+ 1118	— 710
57	+ 1302	" "	— 10 per cent.	+ 1172	+ 462

The computations may be made systematically, as shown in the tabular form. Place in the first column a list of the stations; in the second column, the number of cubic yards of cut or fill between each station and the preceding station; in the third and fourth columns, the kind of material and the proper shrinkage factor; in the fifth column, a repetition of the quantities in cubic yards, except that the excavations are diminished (or increased, in the case of rock) to the number of cubic yards of settled embankment, which may be made from them. In the sixth column, place the *algebraic sum* of the quantities in the fifth column (calling cuts +, and fills —) from the starting point to the station considered. These algebraic sums at each station will be the ordinates, drawn to some scale, of the mass curve. (See Fig. 2.)

The scale to be used will depend somewhat on whether the work is heavy or light, but for ordinary cases a scale of 2,000 to 5,000 cubic yards per inch may be used. Drawing these ordinates to scale, a curve, *A*, *B* . . . *G*, may be obtained by joining the extremities of the ordinates.

Properties of the Curve.

(1) The curve will be rising while over cuts, and falling while over fills.

(2) A tangent to the curve will be horizontal (as at *B*, *D*, *E*, and *F*), when passing from cut to fill, or from fill to cut.

(3) When the curve is *below* the " zero line," it shows that material must be drawn *backward* (to the left); and *vice versa*, when the curve is *above* the zero line, it shows that material must be drawn *forward* (to the right).

(4) When the curve crosses the zero line (as at *A* and *C*), it shows (in this instance) that the cut between *A′* and *B′* will just provide the material required for the fill between *B′* and *C′*, and that no material should be hauled past *C′*, or, in general, past any intersection of the mass curve and the zero line.

(5) If any horizontal line be drawn (as *ab*), it indicates that the cut and fill between *a′* and *b′* will just balance.

(6) When the center of gravity of a given volume of material is to be moved a given distance, it makes no difference (at least,

theoretically) how far each individual load may be hauled, or how any individual load may be disposed of. The summation of the products of each load times the distance hauled will be a constant, whatever the method, and will equal the total volume times the movement of the center of gravity. The *average haul,* which is the movement of the center of gravity, will, therefore, equal the summation of these products divided by the total volume. If we draw two horizontal parallel lines at an infinitesimal distance, dx, apart, as at ab, the small increment of cut, dx at a', will fill the corresponding increment of fill at b', and this material must be hauled the distance, ab. Therefore, the product of ab and dx, which is the product of distance times volume, is represented by the area of the infinitesimal rectangle at ab, and the total area, A, B, C, represents the summation of volume times distance for all the earth-movement between A' and C'. This summation of products divided by the total volume gives the average haul.

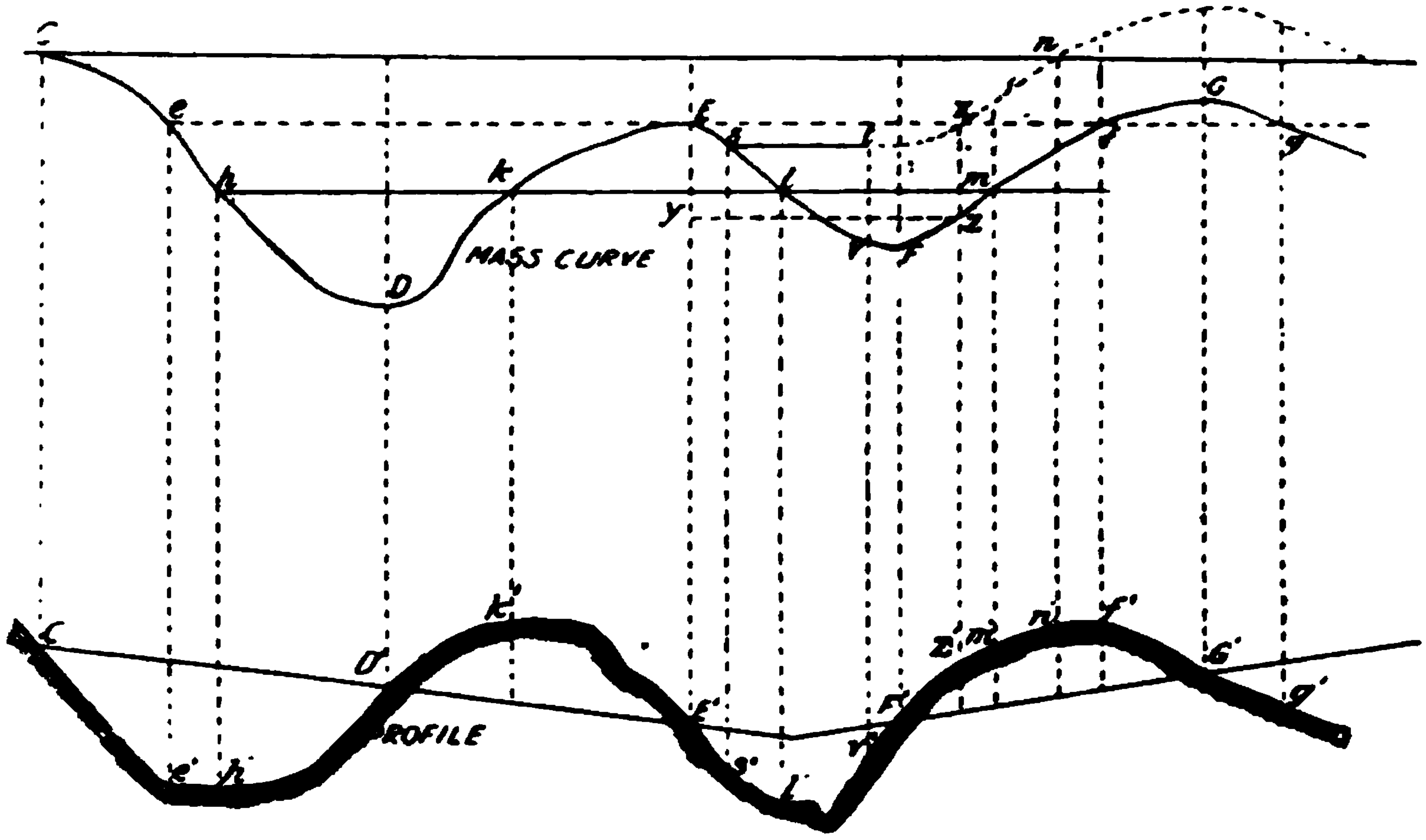


FIG. 3.—MASS CURVE AND PROFILE, SHOWING SPECIAL FEATURES.

(7) The horizontal line (see Fig. 3), tangent at E, and cutting the curve at e, f, and g, shows that the cut and fill between e' and E' will just balance and that a *possible* method of hauling (whether desirable or not) would be to "borrow" earth for the fill between C' and e', use the material between D' and E' for the fill between

e' and D' and similarly balance cut and fill between E' and f' and also between f' and g'.

(8) Similarly the horizontal line $h\ k\ l\ m$ may be drawn cutting the curve, which will show another *possible* method of hauling. According to this plan, the fill between C' and h' would be made by borrowing; the cut and fill between h' and k' would balance; also that between k' and l' and between l' and m'. Since the area $e\ h\ D\ k\ E$ represents the measure of haul for the earth between e' and E', and the other areas measure the corresponding hauls similarly, it is evident that the sum of the areas $e\ h\ D\ k\ E$ and $E\ l\ F\ m\ f$, which is the measure of haul of all the material between e' and f', is largely in excess of the sum of the areas $h\ D\ k$, $k\ E\ l$ and $l\ F\ m$, plus the somewhat uncertain measures of haul due to borrowing material for $e'\ h'$ and wasting the material between m' and f'. Therefore, to make the measure of haul a minimum, a line should be drawn which will make the sum of the areas between it and the mass-curve a minimum. Of course, this is not necessarily the cheapest plan, as it implies more or less borrowing and wasting of material which *may* cost more than the amount saved in haul. The comparison of the two methods is quite simple, however. Since the amount of the fill between e' and h' is represented by the *difference* of the ordinates at e and h, and similarly for m' and f', it follows that the amount to be borrowed between e' and h' will exactly equal the amount wasted between m' and f'. By the first of the above methods the haul is excessive, but is definitely known from the mass diagram and all of the material is utilized; by the second method the haul is reduced to about one-half, but there is a known quantity in cubic yards wasted at one place and the same quantity borrowed at another. The length of haul necessary for the borrowed material would need to be ascertained; also the haul necessary to waste the other material at a place where it would be unobjectionable. Frequently this is best done by widening an embankment beyond its necessary width.

(9) Suppose that it were deemed best, after drawing the mass curve, to introduce a trestle between s' and v', thus saving an amount in fill equal to $t\ v$. If such had been the original design, the mass curve would have been a straight horizontal line between

s and t, and would continue as a curve which would be at all points a distance $t\,v$ above the curve $v\,F z m f G g$. If the line Ef is to be used as a zero line, its intersection with the new curve at x will show that the material between E' and z' will just balance if the trestle is used and that the amount of haul will be measured by the area between the line Ex and the broken line $Estx$. The same computed result may be obtained without drawing the auxiliary curve $t x n$ . . . . by drawing the horizontal line zy at a distance xz ($= t\,v$) below Ex. The amount of the haul can then be obtained by adding the area between Es and the horizontal line Ex, the rectangle between st and $E\,x$ and the irregular area between vFz and $y \ldots . z$ (which last is evidently equal to the area between tx and $E\,..\,x$). The disposal of the material at the right of z' would then be governed by the indications of the profile and mass curve which would be found at the right of g'. In fact, it is difficult to decide with the best of judgment as to the proper disposal of material without having a mass curve extending to a considerable distance each side of that part of the road under immediate consideration.

Area of the Mass Curve.

The area may be computed most readily by means of a planimeter, which is capable with reasonable care of measuring such areas with as great accuracy as is necessary for this work. If no such instrument is obtainable the area may be obtained by an application of "Simpson's rule." The ordinates will usually be spaced 100 feet apart. Select an *even* number of such spaces, leaving, if necessary, one or more triangles or trapezoids at the ends for separate and independent computation. Let $y_0 \ldots y_n$ be the ordinates, *i.e.*, the number of cubic yards at each full station of the mass curve, the figures in column six of the above tabular form. Let the uniform distance between ordinates (=100 feet) be called 1, *i.e.* one *station*. Then the units of the resulting area will be cubic yards hauled one station. Then the

$$\text{Area} = \tfrac{1}{3}\left[y_0 + 4\,(y_1 + y_3 + \ldots y_{(n-1)}) + 2\,(y_2 + y_4 + \ldots y_{(n-2)}) + y_n\right]$$

When an ordinate occurs at a substation, the best plan is to ignore it at first and calculate the area as above. Then if the difference involved is too great to be neglected, calculate the area

of the triangle having the extremity of the ordinate at the substation as an apex and the extremities of the ordinates at the adjacent stations as the ends of the base. This may be done by finding the ordinate at the substation that would be a proportional between the ordinates at the adjacent full stations. Subtract this from the real ordinate (or *vice versa*) and multiply the difference by $\frac{1}{2} \times 1$. An inspection will often show that the correction thus obtained would be too small to be worthy of consideration. If there is more than one substation between two full stations the corrective area will consist of two triangles and one or more trapezoids which may be similarly computed—if necessary.

When the zero line (Fig. 3) is shifted to eE, the drop from Cn to E is known in the same units, cubic yards. This constant may be subtracted from the numbers (column six in the tabular form) representing the ordinates and will thus give, without any scaling from the diagram, the exact value of the modified ordinates.

LIMIT OF "FREE-HAUL."

It is sometimes specified in contracts for earthwork that *all* material shall be entitled to free haul up to some specified limit (say 500 or 1,000 feet) and that all material drawn farther than that shall be entitled to an allowance on the *excess* of distance. It is manifestly impracticable to measure the excess for each load, as much so as to measure the actual haul of each load. The mass curve also solves this problem very readily. Let Fig. 4 represent a profile and mass curve for about 2,000 feet of road and suppose that 800 feet is taken as the limit of free haul. Find two points, a and b, in the mass curve *which are on the same horizontal line* and which are 800 feet apart. Project these points down to a' and b'. Then the cut and fill between a' and b' will just balance and the cut between A' and a' will be needed for the fill between b' and C'. In the mass curve, the area between the horizontal line $a\,b$ and the curve $a\,B\,b$ represents the haulage of the material between a' and b' which is all free. The rectangle $a\,b\,m\,n$ represents the haulage of the material in the cut $A'\,a'$ across the 800 feet from a' to b'. This is also free. The

sum of the two areas $A\,a\,m$ and $b\,n\,C$ represents the haulage entitled to an allowance, since it is the summation of the products of cubic yards times the *excess* of distance hauled.

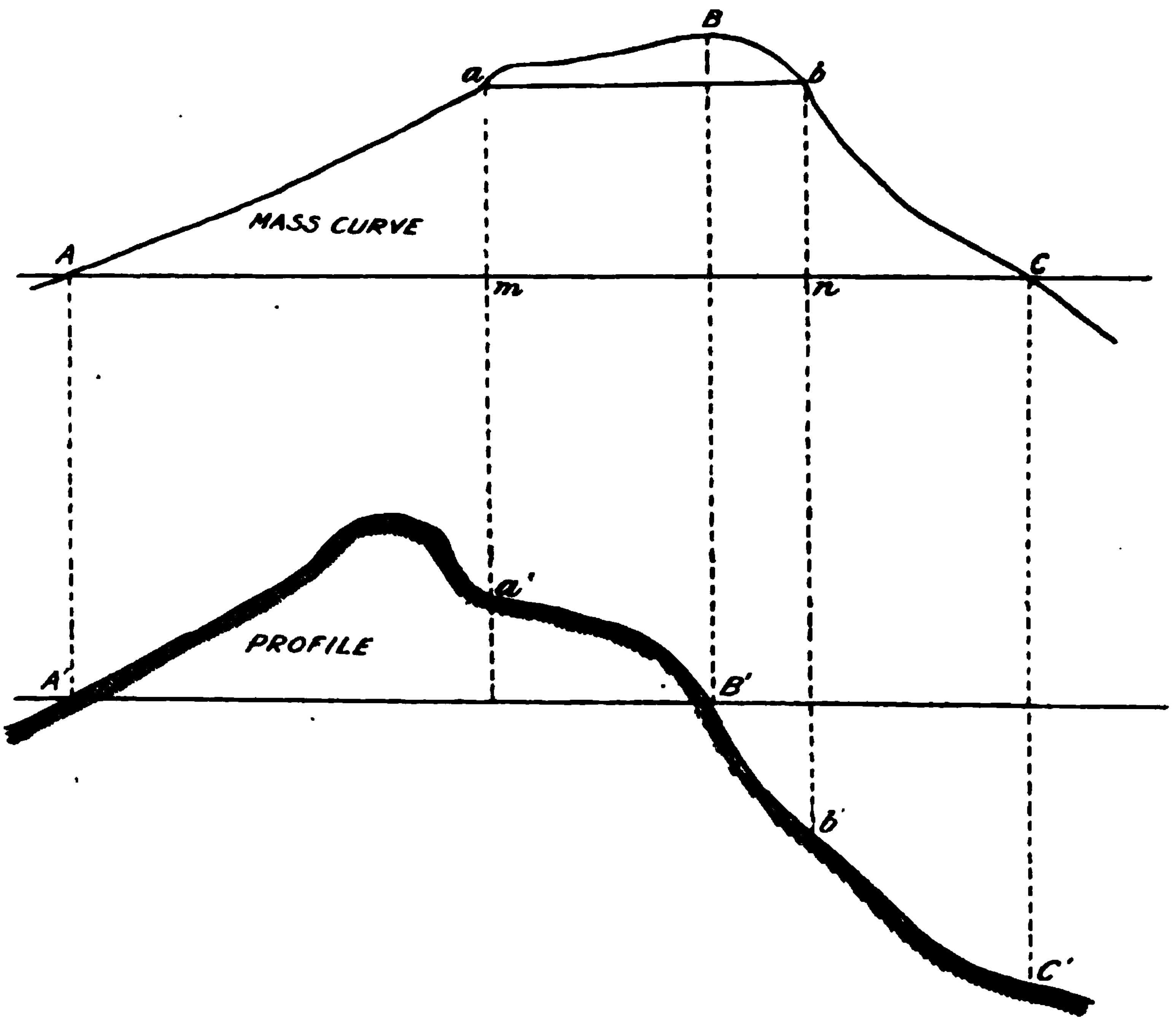


FIG. 4.—MASS CURVE AND PROFILE, ILLUSTRATING LIMIT OF FREE HAUL.

If the amount of cut and fill was symmetrical about the point B', the mass curve would be a symmetrical curve about the vertical line through B, and the two limiting lines of free haul would be placed symmetrically about B and B'. In general there is no such symmetry, and frequently the difference is considerable. The area $a\,B\,b\,n\,m$ will be materially changed according as the two vertical lines $a\,m$ and $b\,n$, always 800 feet apart, are shifted to the right or left. It is easy to show that the area $a\,B\,b\,n\,m$ is a *maximum* when $a\,b$ is horizontal. The minimum value would be obtained either when m reached A or n reached C, depending on the exact form of the curve. Since the position for the minimum value is manifestly unfair, the best definite value obtainable is the maximum, which must be ob-

tained as above described. Since $aBbnm$ is made maximum, the remainder of the area, which is the allowance for overhaul, becomes a minimum. The areas Aam and bCn may be obtained with a planimeter or by the application of Simpson's rule. If the whole area $AaBbCA$ has been previously computed, it may be more convenient to compute the area $aBbnm$ and subtract it from the total area.

Since the intersections of the mass curve and the "zero line" mark limits past which no material is drawn, it follows that there will be no allowance for overhaul except where the distance between consecutive intersections of the zero line and mass curve exceeds the limits of free-haul.

Frequently all allowances for overhaul are disregarded; the profiles, estimates of quantities, and the required disposal of material, are shown to bidding contractors and they must then make their own allowances and bid accordingly. This method has the advantage of avoiding possible disputes as to the amount of the overhaul allowance and is popular on this account. On the other hand the facility with which different plans may be studied and compared would lead to the adoption of a better plan and the elimination of uncertainty would lead to a safe reduction of the bid.

Value of the Mass Curve.

The great value of the mass curve lies in the readiness with which different plans for the disposal of material may be examined and compared. When the mass curve is once drawn, it will generally require only a shifting of the horizontal line to show the disposal of the material by any proposed method. The mass curve also shows the extreme length of haul that will be required by any proposed method of disposal of material. This brings into consideration the "limit of profitable haul." With each method of carrying material there is some limit beyond which the expense of hauling will exceed the loss resulting from borrowing and wasting. With wheelbarrows and scrapers the limit of profitable haul is comparatively short, with carts and tramcars it is much longer, while with locomotives and cars it may be several miles. If, in Fig. 3, eE or Ef exceeds the limit

of profitable haul it shows at once that some such line as $h\ k\ l\ m$ should be drawn and the material disposed of accordingly.

In conclusion I wish to especially emphasize the point in regard to the reduction of the bid for earth work rendered possible by this method. You know that the average railroad contractor is a man who is very apt to make his estimate according to "judgment." He will look at the profile and from a mere inspection of it will make his estimate, and, of course, his experience will often enable him to make a close estimate as to what he could do in disposing of that material. When a graphical method, based upon mathematical principles, is employed, the guesswork is reduced, assuming, of course, that judgment is used in allowing properly for shrinkage, etc. It is possible to so diminish the uncertainty of it that a railroad may specify a disposal of material and thereby reduce the necessary expenses and bring the cost of the earthwork to a minimum. Then the specifications can be submitted to the contractors and they can at once see that the work will cost them a certain sum. By reducing the uncertainty of the work the bid can safely be reduced and probably will be.

DISCUSSION.

A. E. Lehman.—I would like to ask to what extent the author has used this curve in establishing grades; not only in calculating after grades are established, but in laying out grades.

Prof. Webb.—I may say that my personal experience has been as a teacher rather than as a practical engineer. I have never had occasion to use this curve for practical work, except in teaching it to students, and in such field work as the students do. I can certainly see the value in regard to its bearings on establishing a grade line, because, after establishing a grade line and making computations as to the amount of cut and fill, one can then go to work readily and by drawing various "zero lines," as I call them, may determine what disposal of material may be made according to that particular grade line. Then, if it is desired to study another grade line, it may readily be done and the changes to be made will be readily made. The strong point of this method is the fact that the engineer in his office can study a half dozen different plans with great facility, and a glance will often show him that the maximum hauling will be excessive, and therefore that some particular plan should not be adopted, but that he must try some other plan.

E. M. Nicholls.—The only uncertain point that I can see is the shrinkage of the embankments; otherwise I cannot see that there is any fault to be found with the method. It certainly cannot help but enable the engineer to so proportion his grades as to get a minimum of economy within certain limits. Particularly is it of value to an engineer in the field to answer lots of questions which the contractor or sub-contractor may spring on him at any moment. I know very often I have had to answer questions which have involved labor for myself and rodmen for four or five hours.

I may say further, there has been considerable trouble with contractors in computing overhaul for the reason that where there are borrow pits and the specifications say that all earthworks shall be measured in embankments, the shrinkage will cut less figure, or the increase you will get from rock work will cut less figure. The general rule of the ordinary specification was—I have not done any railroad work for several years—that everything is measured in excavation.

D. A. Hegarty.—We have used that method, but not for measuring up for the contractor. We used the method for arriving at the grade and distribution of the material. For the contractor it generally always is provided in specifications, to make up estimates from measurement of material excavated from cut.

Prof. Webb (in reply to an inquiry as to how, in the event of a change of grade, the zero line is changed to equalize the cuts and fills).—Whenever the grade is changed the volume is utterly changed and one must begin over again, make a new column of figures, draw a new mass curve and make new calculations. The grade-line cannot be changed at all without changing the whole thing. Of course, in the case of a river, or very deep ravine, that has to be crossed by a viaduct, no material can be hauled past that and the mass curve will end there. On the other side of the river it will be necessary to begin a new mass curve. That is, a mass curve need only be considered in sections between intersections of the mass curve with the zero line.

Mr. Nicholls.—In regard to making those changes I would suggest that one could alter the zero lines from a perfectly horisontal one to arrive at the result obtained in that way. Of course it is necessary when any change is made, to decide upon the permanent grade line and re-compute the mass area from that. For preliminary work in making an estimate to get the proper grade line for the cut and fill, I think the zero line could be thrown from a perfectly horizontal one without making any deduction.

Prof. Webb.—I think one objection to doing that is this, the mass

curve is formed from ordinates which represent in each case the amount of cut and fill from some starting point to that point. As soon as the grade line is changed those ordinates are changed. Therefore, changing the direction of the zero line would not answer, because the curve itself has to be altered.

L. Y. SCHERMERHORN.—It occurs to me that the mass curve involves the difference between place measurement and fill which has to be assumed. Prof. Webb assumed it in the illustration he used as 10 per cent. for earth. 10 per cent. to 12 per cent. is about the average taken by engineers. It must differ in all classes of material. In our experience the question is asked what is the difference between scow and place measurement? It is very frequently assumed at 20 per cent., that is that scow measurement is 20 per cent. in excess of place measurement. We find from observation in material largely composed of sand that scow measurement exceeds place measurement by about 12 to 15 per cent. If the material is gravel it may be as low as 10 per cent. In clay, which comes up in quite large masses in the dippers and goes to the scow in that condition, we find the scow measurement increased as high as 25 per cent. So in gravel, where the coefficient is least to the plastic clays, where the coefficient is largest, we have a difference probably of 15 per cent. In railroad work there would not be quite so wide limits as I have indicated, but they would vary considerably from 10 per cent.—perhaps more upon the far side of 10 per cent. than from the near side. It seems to me that the argument Prof. Webb makes must be based upon an arbitrary conclusion as to the relation between the measurement of excavation and fill.

PROF. WEBB.—I may have been misunderstood in regard to the matter of coefficient of shrinkage. There is no necessity for employing the same coefficient throughout. The line of road goes through a certain cut and it is assumed that it is, *e.g.*, in sandy soil and would have a certain coefficient of shrinkage in the settled embankment made from it, and that is used in the column of figures in changing the volume of excavation made. The next excavation encountered will be seen to consist of so many yards of loamy soil and so many of rock, and it will be necessary to figure up the equivalent volume of settled embankment which will be furnished from that excavation as it is made. So many yards of loam, with coefficient of shrinkage for that and for the rock, a coefficient for expansion are taken, and then in the fifth column is put down what it amounts to, in fact, just what amount in cubic yards it is estimated will be made in settled embankment from so many yards of excavation. The engineer must always vary his calculation according to the conditions, and so it depends upon the judgment of the engineer as to what will be the coefficient of expansion.

MR. SCHERMERHORN.—The coefficient will increase as the height of the embankment increases.

MR. NICHOLLS.—As I remarked before, the uncertain part is the shrinkage; not only the height of the embankment, but the method of handling cuts a figure. We know that whether we use the drag or wheel scraper, and the method in which you deposit it in the bank, whether from a narrow ridge in center, or whether you bring it up level from the bottom all through, makes a difference in the shrinkage. The team will tramp over it as much with a scraper load of one-fourth yard as with a wagon that hauled a yard and a half. The wagon would compact more than the scraper for one load, but in the aggregate it would be much less. The only way that can be used as a guide to go by in settling up between the contractor and the company in regard to excess of hauling is to have the specification determine the allowance for shrinkage. It is a matter of estimate, and if left open each man can estimate according to his own judgment.

THOS. G. JANVIER.—Regarding coefficient for shrinkage, in all my practice I have foreseen the trouble with the contractor in reference to that, and have made my specifications to cover it by saying that the contractor will be paid for his excavation measured in the excavation, no allowance for fill. In that way there is no allowance for settlement, and if the contractor understands that in the beginning he is perfectly satisfied with the measurements and there has never been any dispute about allowance for shrinkage. I remember one case where the fill was in a low point of work and in the filling a dam was made where a large amount of water collected and we kept filling in there for a long time, it settled very much. The contractor claimed he should be paid for settling in the fill, but the specification said he should be paid in the excavation and of course there was no difficulty about settlement.

MR. LEHMAN.—My experience corresponds closely with Mr. Janvier's and I do not see that it is necessary to continue the discussion on that line. I think I see how this mass curve can be used for the purpose of ascertaining the ideal grade line in a railroad location. When an engineer seeks to establish a railroad location, it should be his aim and duty to obtain the most perfect line the topography will allow. There always exists an ideal line and his purpose should be to hunt for and lay down such a line, so long as he can be governed simply by engineering conditions.

Such a line once staked out, next in order is the fixing of a suitable grade line to it. As there is no definite rule by which this can be done it is always a difficult task to those not particularly experienced in such work. This experience is about all the locating engineer has to depend

on, and with it and by "rule of thumb" he usually settles the question. Hence I can see how the mass curve method might reduce such labor to much more exactness and lessen the difficulty of equalizing the excavation and embankments and adjusting them to the maximum grade.

It appears to me, however, that the use of the mass curve should be called into service, if available at all, before the work of construction begins, rather then after, and not only used in the questions of haul. I know well the difficulty of establishing a theoretically correct grade line on a fixed location. As far as I know there are no satisfactory rules to govern this, and if the mass curve will prove effective to this end it will certainly be a boon to the locating engineer.

THE PRESIDENT.—In my experience the establishing of a grade line is generally fixed to a maximum grade, and it is not always possible to equalize the cuts and fills. For instance, in going across a long meadow from one hill to another, if your location is for a trunk line railroad you could not in all cases equalize the cuts and fills there. If, however, you are making a location for a cheap railroad you may be able to equalize in the cuts and fills, but in making the bold location you should keep your grades up to an easy line and borrow material from a side ditch or elsewhere. As to the shrinkage and the paying of the contractor, my experience has been very much in the way mentioned by Mr. Janvier. We pay for the material taken from the excavation and nothing measured in the fill. We also avoid classification as far as practicable, *i.e.*, the contractor takes rock and earth and everything he finds in the cut, all at the same price per cubic yard.

In some cases I have put railroad work under contract at a price per mile, for all graduation complete, ready for the ballast and track. This further simplifies the matter and eliminates completely all classification and price per quantity of material moved—and has the advantage of enabling those interested in building a railroad to know to a certainty what it will cost as soon as it is placed under contract to a responsible contractor. This I would recommend where the grading is light. For very heavy cutting and filling, with bridge work it is a little too general.

Contractors are not ignorant by any means. They are generally shrewd, intelligent business men—that is, a successful and reliable contractor—and to-day, to make himself fully equipped, associates himself with an engineer; so the two are found to be a little more than equal to the engineer on the other side of the contract. So it is well to eliminate the old method of classification for earth, loose rock, solid rock and hard pan, so common to all of us, and it will save us from much discussion and difficulties, often very hard to settle, and not unfrequently ending in the

courts. I think, nevertheless, that this graphical method laid down by Prof. Webb will be very beneficial in many ways and I do not see why engineers and contractors should not take hold of it. It will save them lots of time and I am glad to see it so well illustrated.

MR. JANVIER.—I remember a very interesting case I once had with a contractor. He had a great deal of heavy rock excavation and also a heavy fill right along the bank of a river. I took my cross-sections and soundings down to the mud, found quite a steep slope into the river, some places running down 20 feet; and in my specifications I mentioned the fact and also specified that the contractor should fill in first with the stone from the excavations and afterwards he should fill in with earth. He seemed to think he knew better how to do it and commenced filling in with the dirt, dumping it into the water. After getting in many thousand yards of it he put stone on top. You can imagine the result. It all went out into the river and he had to commence over again. He tried to put the blame on the engineer, but the specifications settled the matter and he had to begin over again.

MR. NICHOLLS.—Mr. Janvier entirely omits to say anything in his specification about overhaul. Prof. Webb's paper is important on that one subject, in determining the manner in which material shall be handled. It is a common thing to say no earth shall be wasted above the grade between certain points. The contractor as a general rule wants to know where he is going to dispose of that material; and if bound down by certain regulations and restrictions he wants to know what his overhaul is going to be. That is where the method will have the most value.

NOTES AND COMMUNICATIONS.

THE ENGINEERING CHEMISTRY OF CLAY.

AT the meeting of September 18, 1897, Dr. Henry Leffmann, by means of blackboard formulas, described the composition of clay, and exhibited four samples of material in which the pure clay had been separated from foreign matters in a way to show the percentage of each. He described the physical formation of clay, and showed the character of rock from which the clay is obtained, by projecting thin sections upon the screen by means of the electric lantern with microscope and polarizing attachments.

Mr. Harrison Souder cited a case at Germantown, Philadelphia, where a perfectly water-tight dam was made accidentally by a pile of mica-schist and quarry-refuse which had been dumped in a gully.

Prof. Lewis M. Haupt (visitor) called attention to the incompleteness of our information regarding clay, and stated that the best substance for reservoir-lining was a mixture of 60 parts of gravel, 22 parts of sand and 18 parts of clay. He also called attention to the permanence of clay-banks in tropical countries, and the advantage of cutting out the clay vertically, instead of on a slope.

Mr. John C. Trautwine, Jr., described the clay which had been got from the neighborhood to line the Queen-Lane Reservoir, and attributed its porosity to the large amount of mica which it contained.

Mr. Max Livingstone called attention to the use of clay for the refining of certain oils.

At the same meeting Mr. Joseph T. Richards exhibited and described lantern-views of a small dam which he had built in the neighborhood of Philadelphia, and lined satisfactorily with the clay found in that locality; also views of the larger dam at South Fork.

BREAK IN LARGE MAIN.

AT the meeting of October 2, 1897, Mr. John C. Trautwine, Jr., called the attention of the Club to several matters which had recently occupied the attention of engineers in the Philadelphia Bureau of Water, including a break in a 30-inch main, the character of mud deposit in a reservoir, and the method of calculating the pressure on a valve in a pass-pipe through a reservoir embankment.

ABSTRACT OF MINUTES OF MEETINGS OF THE CLUB.

REGULAR MEETING, September 18, 1897.—The President, Joseph T. Richards, in the chair. Fifty-one members and visitors present.

Dr. Henry Leffmann made a verbal communication on "The Engineering Chemistry of Clay." The subject was discussed by Messrs. Richards, Souder, Trautwine and Livingston and L. M. Haupt (visitor).

BUSINESS MEETING, October 2, 1897.—The President, Joseph T. Richards, in the chair. Sixty-eight members and visitors present. The tellers of election reported that Messrs. Geo. C. Davis and Johnson Hughes, Jr., had been elected active members. The following resolution was adopted:

"That there shall be established a standing committee of seven members, appointed from the active membership, to be called *The Committee on the Relations of the Engineering Profession to the Public.*

"That said committee shall be appointed by the President as soon as practicable after his election, and shall serve until its successor is appointed.

"It shall be the duty of this committee to inform the Club of any public action or contemplated legislation, national, State or municipal, affecting the engineering profession as a body or the rights and privileges of engineers, and to perform such other duties concerning the relations of the Club to the public as may from time to time be referred to it."

Prof. J. M. Porter read a paper on "The Delaware River Bridge at Easton, Pa." The subject was discussed by Messrs. John C. Trautwine, Jr., Harrison Souder, F. Schumann, E. F. Smith, Joseph T. Richards, and R. L. Humphrey.

REGULAR MEETING, October 16, 1897.—The second Vice-President, Henry Leffmann, in the chair. Sixty-seven members and visitors present. The death of Mr. C. G. Hildreth, associate member, was announced. Mr. L. Y. Schermerhorn read a paper entitled "Breakwater Construction on the American Coast." The subject was discussed by Messrs. Birkinbine, Christie, Marburg and Webb.

REGULAR MEETING, November 6, 1897.—The President, Joseph T. Richards, in the chair. Seventy-one members and visitors present.

A resolution was adopted commending the project for an industrial exhibition to be held under the joint auspices of the Franklin Institute and Philadelphia Commercial Museums.

Mr. Benjamin Franklin read a paper on "Some Features of Stone-Road Construction." The subject was discussed by Messrs. Janvier, Hegarty, Nicholls, Christie, Furber, Webb, Schermerhorn, Fuller, and Leffmann.

BUSINESS MEETING, November 20, 1897.—The President, Joseph T. Richards, in the chair. Fifty-five members and visitors present.

The President announced that the Board of Directors had decided that it would be appropriate to celebrate the twentieth anniversary of the organization of the Club, December 17, 1897, and that a special committee had been appointed to make arrangements. Mr. Eglin, the chairman of the committee, explained that the celebration would probably take the form of a dinner, and stated that full particulars would be sent to all the members shortly.

The Secretary, under instructions from the Board of Directors, called attention to the fact that a stated meeting of the Club would fall on the evening of New Year's Day, and as it was thought that there would be few members present at that time, the President was requested to call a special meeting for the following Saturday, January 8, 1898, to transact the regular order of business.

The tellers reported that at the election held on this date, Messrs. Howard C. Baird, Arthur B. Davenport, Jr., J. W. Ladoux, and Henry S. Spackman were elected to active membership, and Mr. Percy H. Wilson to junior membership.

Prof. Walter L. Webb presented a paper on "The Mass Curve in Earth Work Computations." The subject was discussed by Messrs. Lehman, Nichols, Richards, E. F. Smi h, Schermerhorn and Janvier.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

SPECIAL MEETING, Friday, September 17, 1897.—Called to transact all pending business. Present: The second Vice-President, Directors Livingston, Schermerhorn, Eglin, Hartley and Ott; the Secretary and the Treasurer.

The Treasurer's report showed a balance on hand, September 1st, of $1395.81.

The Secretary called attention to the fact that the twentieth anniversary of the Club's organization would occur on December 17th next, and a joint committee was appointed, consisting of the Information and House Committees of the Board, to consider the advisability of having a celebration at that time, and the form which it should take.

SPECIAL MEETING, October 12, 1897.—Called by general consent to transact all pending business. Present: The Vice-Presidents, Directors Livingston, Eglin, Hartley and Ott, and the Secretary.

Routine business was transacted.

STATED MEETING, Saturday, October 16, 1897.—Present: The second Vice-President, Directors Livingston, Schermerhorn, Eglin, Hartley, Schumann, and the Secretary.

Routine business was transacted.

REGULAR MEETING, Saturday, November 20, 1897, 4.15 P.M.—Present: The Vice-Presidents, Directors Livingston, Schermerhorn, Eglin, Hartley, Schumann and Ott, and the Secretary.

The Treasurer's report showed:

Balance from August	$1,395 81
Receipts in September	112 60
	$1,508 41
Expenditures in September	255 23
Balance September 30, 1897	$1,253 18
Receipts in October	262 50
	$1,515 68
Expenditures in October	1,059 88
Balance October 31, 1897	$455 80

Resignations of Mr. H. Warren K. Hale, and Mr. George S. Barrows, from membership, were accepted.

The Publication Committee reported that the publication contract had been dissolved, and that Messrs. Armstrong & Fears had been authorized to act as advertising agents of the Proceedings.

[Proceedings Engineers' Club of Philadelphia, Vol. XIV, No. 4, January, 1898.]

Joseph T. Richards

Twentieth President of the Club,
January 16, 1897–January 15, 1898

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.
INCORPORATED JUNE 9, 1892.

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ANNUAL ADDRESS OF THE RETIRING PRESIDENT

JOSEPH T. RICHARDS.

Delivered January 15, 1898.

GENTLEMEN:—If there were some new way of expressing thanks more pointed and convincing than the old ways, I should not fail, as I am likely to do, in conveying to you, this evening, an adequate sense of the gratitude I have felt throughout the past year for your indulgence, help, and favor. Restricted, however, to well-worn phrases, I can only assure you that the time of my presidency will always remain to me a happy memory, not only on account of the honor which I hold this presidency to be, but also on account of the growth and progress we have made as a club, and of the harmony that has marked our proceedings. It is cause for congratulation that we have rounded out another year of good-fellowship and mutual helpfulness; while the able keeping to which we will trust our fortunes for the coming year gives promise of still wider success.

A twelve-month ago, when your kindness made necessary some inaugural words from me, I spoke of what was then, and still is, very near my heart, in relation to the new building which this club deserves, and which, in conjunction with similar clubs of Philadelphia, it owes itself. The subject has not lain idle during the year. The growing importance of engineering as a profes-

sion, the impetus lately given to all kinds of building, the improved finances of our club, the increasing need of union among engineers, all point, I believe, to a time not far off, when a federation of Philadelphia scientific societies will be lodged in a building worthy of its tenants. I am the more hopeful of our work, because of the success of kindred associations within the past year in New York and Paris. Not two months ago, the American Society of Civil Engineers opened in our neighboring metropolis a handsome club-house in what seems to me, considering the esthetic and refining influence of our profession, a significant position: next door is the Central Presbyterian Church, opposite is the gallery of the Fine Arts Society, and around the corner is the Carnegie Music Hall. The American Society, it is true, has a wider membership than ours, and a larger revenue; but, on the other hand, their building, which cost $200,000, is devoted entirely to their own use, while ours, if of equal cost, might, by means of a rent-roll, become a source of profit; or, if small in proportion to our means, would require a more moderate outlay. I am aware that *time* is necessary to mature the idea; only let it not become forgotten.

The year lately closed has seen in this neighborhood an extraordinary growth in building. Indeed, our city has never before witnessed in so brief a time the rise of so many tall structures. Whatever may be thought of the "sky-scraper" as a thing of beauty, safety, or profit, it is in one way a gigantic success—and that is as an engineering product. I need not recount the difficulties which have been overcome by those who are to build a twenty-fifth story, and yet remove it but a few seconds above the street. The audacity of the idea is lost sight of in its frequent fulfilment. One can only with difficulty realize what engineering has done within twenty years for the material needs of the business world in the way of architecture. And no one of us need be ashamed, if the glow of pride warms his heart on looking at the great fabric close by us, which has risen at the touch of the engineer's wand.*

Less directly the outcome of professional work, yet of such vast possible importance to our city and the country at large that no

* Stephen Girard Building.

local review of the past year, even from our standpoint, would be complete without mention of it, was the establishment in 1897 of the Philadelphia Commercial Museum. When the events of that year are gathered into the pages of history, this enterprise, I venture to predict, will outweigh the growth of navies and the movements of politicians, since it bears the stamp of a heightening civilization, and makes for peace, prosperity, and the healing of the nations. The agents of the Museum are scattered well nigh over the whole commercial world. Our Consular service is actively co-operating in this work. An American manufacturer or merchant in any line can secure definite reports on the conditions he must meet in any foreign market, the extent of trade, prices, duties, packing, shipping and banking facilities. In its library will be the whole literature of manufacturing and commerce. In its museum will be an object-lesson of the business world. The fact that twenty-five Chambers of Commerce in the United States, and forty of those in Spanish-American Republics, are represented on the Advisory Board, and that the Museum is looked upon by the Government at Washington, as well as in all American States, as of international importance, obliges us to rate the Museum high, and as one of the most valuable assets of our nation.

The improvement of our harbor, which has been in progress since June, 1893, has been completed within a few months. We have now a well established channel 2,000 feet in width, from 26 to 30 feet deep at low tide, and extending from the new bridge to Kaighn's Point, a distance of about six miles. To accomplish this, 20,800,000 cubic yards of material were removed, including 125 acres of solid land in Smith's, Windmill and a part of Petty's Island. Moreover, the river channel has been deepened to the capes, so that now it is nowhere less than 300 feet wide and 26 feet deep. The new bulkheads along Delaware Avenue are being extended to make the street 150 feet broad, while 15 new piers have been lengthened to the new exterior pier line, making them from 500 to 600 feet long. All these changes have greatly improved our water front, have added to our shipping facilities, and will, we trust, materially promote our commerce.

In contrast with the commercial, is the military strengthening of our country. Near our city, we notice new emplacements,

new guns, and other improvements at and near Fort Delaware. The defences at the mouth of our river are regarded as the best on the coast. These defences will contain a large number of ten-inch and twelve-inch guns (several now in position), capable of throwing shells a dozen miles, and of piercing a twelve-inch armor plate at half that distance. These guns will have disappearing carriages, by means of which the shock of firing throws back the gun upon hydraulic cylinders and permits it to be loaded out of sight in comparative safety. Furthermore, the channel of the Delaware will be set with secret mines and torpedoes, to be sprung by electric sparks, should a hostile vessel succeed in passing the capes. In the way of floating armaments, the past year has seen the completion at Cramp's yard of our largest war-vessel, the Iowa. No one, be his opinion of its utility what it may, can inspect such a prodigy of strength, such a storehouse of power, without marvelling at the ingenuity, accuracy, and patience of its architects and builders.

Still greater admiration, it seems to me, should be kindled in our minds at thought of those new monsters of the deep, such as the Kaiser Wilhelm der Grosse, and the vessels of the American Line belonging to the International Navigation Co., and their prodigious achievements. Personally, I am a little fond of statistics in matters of this kind, and like to think of a ship that would just fit in between here and the Public Buildings; of the Washington Monument on the Potomac being able to lie in his hold, (for one can scarcely say *her* of those vessels) with fifty feet to spare, at either end; of as many as eighteen water-tight compartments; with three, and even four, graceful funnels; as many as seventy engines, great and small, which devour a train of coal every day, and in which the equivalent of 30,000 horses is at work; their population of 2,000 souls; and their flight like seabirds from shore to shore. These details arouse one's astonishment, but they also awaken a deeper wonder at the energy and capacity of man as represented in our profession, and of his accumulating victory of mind over matter and force.

In regard to railways, the advent of 1898 is marked by only a small increase in our country, less, indeed, than 2,000 miles. The United States, however, continues not only to lead the world

in her mileage of tracks, but falls not very much short of equalling that of all the other continents combined. The railroads of the United States, placed end to end, would span the distance between the earth and the moon; those of China would reach only from New York to Baltimore. As to specific works, that which will connect St. Petersburg with the Pacific Ocean, six and a half thousand miles away, has been driven rapidly forward, so that three daily trains are running each way over the 2,000 miles of road now opened. The locomotives on the Trans-Siberian Railway, it is interesting to note, are nearly all of American make, and our American locomotive builders have within the past year booked large orders for locomotives for Europeon railways in competition with the largest English and Scotch manufacturers.

Bridge building may be said to have achieved much in 1897. This statement finds illustration at Columbia, Pa., where the late wooden bridge of the Pennsylvania Railroad Company, destroyed October 1, 1896, by a terrific wind, has been replaced by one of steel more than a mile in length; the steel work of this bridge was erected in twenty-one working days. A still more notable replacement has been made where the Chicago, Rock Island & Pacific R.R. crosses the Mississippi at Rock Island. Within the memory of some of us, the good people of Iowa opposed bridging that river, lest if the first bridge were allowed, there would in time be one every 50 miles, "to the great mischief of commerce." After the original Rock Island structure was finished, a judge of the U. S. District Court declared it a nuisance, and ordered those piers which stood on Iowa soil to be taken down. A law suit followed, in which the road was represented by Abraham Lincoln, and the judge's order was reversed. At Niagara, the old suspension bridge, which made famous the name of Roebling, has given way to a securer arched one, constructed under the former without interfering with travel. Greater New York is to have a second, if not a greater, suspension bridge over the East River. The span of the new East River bridge will be slightly longer than that of the New York and Brooklyn bridge, and of considerably greater capacity. It will be 118 feet wide, carrying two elevated railway tracks, four

trolley-car tracks, two roadways for common vehicles, and two promenades. The cables will be something over 17 inches in diameter, of steel wire. The anchorages will be 150 feet by 178 feet in plan, and 100 feet high. A work of such magnitude is of national importance, and must attract the attention and admiration of all lovers of the advancement of our young and growing country.

I shall say nothing new to this company in stating that steam and electricity have an acknowledged rival motor in compressed air; that each has its advantages, and seems, under certain circumstances, to be best. There is no general prejudice against compressed air; it has a fair field, as is shown by its use on various railways at home and abroad, at the Anaconda mines, in tunneling, and in many workshops. I have been pleased to learn that the New York post-office has followed the example of our own, though on a much larger scale, in connecting the central with subordinate stations by pneumatic tubes. An interesting race has been run by a pneumatic carrier, a telegram, a wagon, a messenger boy, and a postman. The round trip was made through pneumatic carrier in five minutes, and by the other methods ranging from thirty minutes to one hour. What looks like an epoch-making use of compressed air, has recently been made by Mr. Chauncey N. Dutton, of New York, in a pneumatic lock for canals. Although it has still to be proved by daily use, the invention has been adopted by the State Canal Board of New York, which has ordered five locks at Lockport to be replaced by one of Mr. Dutton's. The possible outcome of this mechanism is almost extravagant; for if ocean vessels of greatest tonnage are to be lifted sixty feet in a few minutes, who shall set limits to inland navigation? The question of how to open a deep and inexpensive waterway from Chicago and Duluth to the sea, a question upon which a presidential commission is at work, and on which the indefinite expansion of the West is thought to depend, may be solved by placing at Niagara, where the 300-foot rock wall has hitherto blocked the way for large boats, a series of only two or three pneumatic locks.

There are several new subways in large towns which no glance at recent engineering progress should fail to include. Passing

by our familiar excavation on Pennsylvania Avenue, I have to mention the completion of the Boston subway and the freedom it gives to traffic in the hitherto crowded streets. An underground belt line, six and a half miles in length and consisting of two parallel tunnels, has been completed in Glasgow. The line passes twice under the Clyde and reaches at places a depth of 125 feet. Where it was driven through rock for more than two miles, compressed air was used for power. In London, still farther down stream than the Tower Bridge, is the New Blackwell Tunnel under the Thames. This circular boring, twenty-seven feet across and over a mile long, was also made by the pneumatic process under great difficulties, owing to the nearness of the river-bed. These enterprises form an interesting commentary on the relation of engineering to civic comfort and municipal growth.

And now, in closing, a few words about our profession. At the present time there is agitation among engineers to determine and establish what has been called the criteria of professional etiquette among ourselves, and a fuller recognition on the part of the public that such a profession exists. There has long been this unrest and anxiety, but at present it is a growing force, and from what I have heard expressed within the past year, it is unmistakable that a better guidance is needed for the varied conditions under which the profession is practised. This was, to some extent, the case in years gone by, when one individual was expected to cover the whole field, but it is still more pressing since the profession has become divided into many specialties. Of the civil, architectural, mechanical, electrical, marine, sanitary, signal and interlocking, military, chemical and metallurgic branches of our art, each furnishes sufficient study for a lifetime. Indeed we might with advantage sub-divide further, for I have found it profitable to classify civil engineers. I choose as locating engineer one who has the natural gift of finding through hill and dale the best line for a road; as constructing engineer, one who excels in building; the bridge engineer has enough to do without going beyond his specialty; as the fourth has who understands well the modern arrangement of yards and terminals, requiring years of study and experience, in order to shift and transfer traffic with greatest economy and dispatch. And following

this comes the later and entirely separate specialty of interlocking and signals for the safe operation of trains. In the same way, I suppose, sub-divisions may be made with equal profit in other branches. All this broadens the professional field, and makes null the popular idea of many years ago, that engineering is not a profession. Since that claim is settled for all time, engineers are right in expecting recognition from the public, the state, and the government. Before this can become satisfactory, there is need, however, for engineers to organize. They must formally recognize their own profession. We must know what constitutes a profession.

I wish to pass this idea along by means of the Engineers' Club of Philadelphia, with the hope that the man may soon appear, fitted to meet this requirement of the time. One could build no other memorial of himself so lasting as a proper convention that would unite all our branches, yet without leveling distinctions, and secure for us that recognition as professional workers which we so justly deserve.

XV.

THE KEELY MOTOR.

By E. A. Scott, Active Member.

Read January 8, 1898.

The Keely motor has been a matter of greater or less public interest for twenty-five years, and yet there is now as little general knowledge of what it is as when it was first announced. Probably no other enterprise making as little actual progress was ever kept alive so long. Certainly no other enterprise ever enlisted so much capital without showing more substantial reasons for investing it.

Keely has carefully guarded his secret; even the courts could not extract it from him. In fact the secret constituted the entire property of which Keely was the treasurer, and even the company formed to exploit his supposed invention, has never been able to wrest it from him. Any effort on the part of the stockholders to do so has been met with the objection that Keely controlled the situation and the value of their property depended upon keeping on good terms with him.

Many investigators, scientific and otherwise, have seen his experiments; United States Government officials and experts have witnessed them; capitalists, with millions at their disposal, have sought to control his inventions, yet there has always been an unreadiness on the part of the inventor to do anything practical; he was always just within reach of the goal, but never got there. He is now over seventy years of age, and the possibilities of his secret dying with him have aroused those who have supplied him with funds to the desirability of having him communicate his knowledge to someone who could continue his work.

With this idea, Mrs. Bloomfield H. Moore, who has for many years been his staunch supporter through evil and good report, and who, with Keely, controls the enterprise, made an effort to find a suitable person to fill that rôle. Well-known scientists who were invited to investigate the subject, courteously declined. This was not surprising, for no person had ever been given a fair opportunity to observe the operation of Keely's apparatus, and it was a mere waste of time to visit his workshop.

In the fall of 1895, Mrs. Moore, who had but a few weeks before returned from Europe, where she has resided for many years, asked Mr. E. A. Scott to make a visit with her to Mr. Keely's laboratory. She was desirous that someone qualified to speak should see enough of what Keely had done to be able to say that he had discovered a force hitherto unknown, and that he had, to some extent at least, succeeded in harnessing it. Mr. Scott had interviewed Keely on the subject in 1874, and was familiar with the results of former attempts to discover the secrets of Keely's laboratory, which had all been negative because of lack of suitable facilities for observation. He was also familiar with the views of the Government experts who witnessed some experiments made by Keely at Fort Lafayette in 1886.

The visit was made November 9, 1895, and the afternoon of that day was pleasantly spent with Keely at his workshop. The impression which the inventor made upon his visitor, which the latter published at the time in a semi-serious article, is given here in a brief extract from that article:

"John W. Keely is 68 years old, although he looks much younger. He is a large, powerfully built man, with a large head, square shaven jaw, with heavy, dark side-whiskers, tinged with gray, and dark eyes which move rapidly. His movements are nervously quick and his speech is extremely rapid, as though it could not catch up with his thought. He impresses one with the belief that he is absorbed in what he calls his life-study, that time is short, and that every nerve must be strained to accomplish practical results while life remains."

A very little conversation satisfied the visitor that he must abandon all preconceived notions of natural philosophy if he thought to make any progress in the study of the new power. The laws of gravity, as laid down by Newton; magnetism, as formulated by Faraday, Henry and others; light and heat, as outlined by Lord Kelvin, and the correlation of forces had to give way to this mysterious force, which practically creates something out of nothing, if we may unquestionably adopt the discoverer's theories.

At this first interview enough was seen to satisfy the visitor that some, at least, of the experiments witnessed did not depend

for their explanation upon any hitherto unknown force. He did not then, nor at any other time, give Keely any reason to think that he did not implicitly believe that the moving force was "Apergy," the name given to this as yet undemonstrated force. Among the experiments witnessed on that first afternoon were (1) The continuing vibration of a short bar of steel which had been "vitalized." (2) The suspension of a heavy weight by simple contact with two small strips of steel, and dropping it by striking a

Aerial Propeller.

tuning-fork. (3) The levitation experiment, by which heavy weights rise and fall in water in response to notes produced on certain pitches. (4) The constant revolution of a small brass wheel after having been put in step with the vibratory force called "Apergy."

The visitor also saw the engine built to navigate an airship, recently described in a city journal as a new invention. He saw the engine, afterwards called a "Vibrodyne," which was to revo-

lutionize all commercial machinery. This was not shown in operation. Keely also showed him a large book for the purpose of explaining the principles of his vibratory philosophy. It was filled with heavy cardboard leaves, covered with pen drawings, all made by Keely with beautiful exactness. Nearly every one of the plates had one or more bars of music, showing the dominant chords or vibrations which governed certain combinations. The inscriptions on the Zuni tablets would have been quite as plain to the visitor, and Mr. Keely kindly enlightened him as to their meaning. In explanation of one of the simpler charts, Mr. Keely said: "The chord of polar negative attraction, so far as this sympathetic research is concerned, proves conclusively that the chord of the neutral center of the polar attractive currents of the earth represents the sympathetic chord of B flat, third octave, one one-hundredth of a note below the octave, according to sympathetic sub-division."

The visitor had before noted that Keely's language, while sounding perfectly familiar so far as the words were concerned, did not convey any ideas. He soon learned that without a knowledge of the application made by Keely of the terms which fell so glibly from his tongue it would be useless to study the subject by question and answer. Some months afterwards he was given some manuscript of Keely's which was said to be the clearest exposition of his views on the great vibratory principle upon which his discovery is based. The first paragraph of this paper, which serves as the introduction to the subject, reads thus:

"The peculiar sympathetic conditions whereby a magnet is conserved to polar and anti-polar currents of the earth show a duality of sympathetic inflow and outflow as to prove anything but perfect sympathetic equations, as between its reception and distribution in that part of the electrical field that represents one of the triplets that in celestial physics is classified as inter-atomic vibratory oscillation. Now, if this oscillation represents in its alternating action a vibratory wave-motion representing in its corpuscular field of action, say 128,400 exchanges per second between polar reception and anti-polar (or depolar) distribution (which sympathetic philosophy proves most conclusively), the fact is established of its perfect sympathetic concordance to that

third of the electrical triplet representing the sixths as classified in sympathetic physics, and thus that line of sympathetic action as represented in the magnet when it is electrically sensitized becomes thoroughly subserved to polar sympathetic attraction as a medium through which a portion of a polar flow is diverted —not latent, but highly active under all conditions as long as its sensitization exists—that is its magnetic sympathy as electrically induced, and associates itself with every medium in nature where this latent element exists, viz: steel, iron, oxygen at a low temperature, etc."

As Keely has made vibratory physics the study of his life, it will be taken for granted that the statement just quoted is authoritative. At the same time the writer confesses that he does not understand it, although it sounds all right.

Mr. Scott left with the understanding that he should make a second visit at some date to be named. In the meantime he discussed the details of what he had witnessed with Mr. Addison B. Burk, President of the Spring Garden Institute, who agreed with him in some of his conclusions, and it was arranged that both would be present at the next visit to Keely, if agreeable to Mrs. Moore. That lady gave her consent, and named November 23, 1895, as the date. It was arranged between them that if the experiments were repeated, each would pay attention to certain details, so as to cover as many points as possible. At this visit the surroundings of the place and arrangement of the rooms constituting the laboratory were noted.

Entrance is made from the street through a large door into a room in which is a carpenter's workbench, some powerful winches, and an assortment of tools; and on one side was an immense box, bound with iron bands, with a cover so heavy that tackle was arranged above it for lifting it. It was closed and padlocked, and was said to contain machinery not now in use. A large door led into a room on the same floor at the rear of the first one, which was not opened on any of the visits. A stairway to the second floor leads to a landing on which are parts of abandoned machinery. A small room on one side of this contains a large desk, with books, instruments and drawings. On the opposite side of the landing is a room somewhat larger, with

many expensive looking instruments, or machines, some of which he exhibited in operation. Back of both of these rooms is a large room the full width of the house, in which some of the apparatus was exhibited. To the rear of this is another room, a step or two higher. This last room is over the back room on the first floor, before referred to. To the north of this building is the central power station of the Columbia Electric Light Company.

One fact, which may or may not be of importance, in connection with all the visits, is that Keely required of Mrs. Moore twenty-four hours' notice of any visit at which exhibitions were to be made. On the second visit, at which Mr. Burk was present, Keely was asked to show the sensitized round steel bar before referred to. He produced it, and a measurement showed it to be $7\frac{1}{2}$ inches long and $1\frac{9}{16}$ inches in diameter, with a small hole through it longitudinally which could be blown through but no light would pass through it; another larger hole was bored through the bar near one end. By striking it on the floor with one end, it would vibrate with a base note like an organ tone which would continue for more than a minute; a blow on the other end produced a note of high pitch not quite so persistent. Keely's explanation of this phenomenon made at the first visit, was that the bar had been "vitalized" and its proportions had been calculated to a nicety. His exact explanation was: "By vitalizing this bar it produces a molecular oscillation of three times the diameter of the molecule, whereas under ordinary circumstances with a piece of forged steel, the oscillation is only one-third of its diameter, 40,000 times a second, which is perfectly inaudible to the ear. By increasing the magnitude of the vibrations by the sensitizing process to three times the diameter, it gives a molecular swing that brings out an oscillation that produces a chord with three different notes."

Mr. Scott had formed a different theory and asked that the bar be weighed. At just this juncture Mr. Keely admitted a caller, a young man with whom he appeared to be well acquainted, and having no scales in his laboratory, he asked the young man to take the bar to a neighboring drug store and have it weighed. He returned, saying its weight was 3 pounds, 3 ounces. During

his absence Keely explained that the sensitizing process consisted in treating the metal with hydrogen in an oven, which would sometimes reduce its weight to nearly half the normal. Making allowances for the rounded ends, the bar had evidently suffered a loss in weight, but not in that proportion. Mrs. Moore told the writer that the bar had created a sensation among scientific gentlemen in Europe, and that there was a standing offer of $10,000 for the production of a similar bar.

To test the truth of their theory and not in the hope of reward, the investigators concluded to have a bar made. After several attempts with vibrating single bars inserted in a bored-out piece of steel, Mr. Burk succeeded in having an exceedingly good imitation made at the Spring Garden Institute, by inserting two ordinary tuning forks of different pitches in the bored-out steel, and concealing the work by screwing on an end piece and then turning the bar off in a lathe. It required more work, probably, than the hydrogen process, but the molecules had the requisite swing, and the notes the proper resonance and persistence. This simply shows that there is possibly more than one way of arriving at the same result. After the duplication of this bar, the original could not be seen.

Mr. Keely on this occasion showed his apparatus for sensitizing bars, and also the amalgam disks which form so conspicuous a feature in all his apparatus. It was a glass receiver, from which the air could be exhausted by an air-pump, with an opening at the bottom large enough to admit the object to be sensitized, which must be mounted on glass. The opening was closed with a screw cap. The objects to be treated must not be touched by the hand, as by so doing vibrations might be set up in the body which would defeat the purpose. When the treatment was completed the disks could be handled without detriment.

The disks referred to were about 2½ or 3 inches in diameter, of brass, and an inch thick, with the center turned out, making it like a cap, or cover of a jar. The cap was then filled with an amalgam and finished off smooth, like the obverse brass face of the disk. Keely said the composition of this amalgam had cost him some years of study. It melts at so low a temperature that he had caused much amusement by having spoons made of it,

which when put into a cup of hot coffee would melt and disappear. The brass face of the disk was gold plated, which Keely said was essential.

On this visit the levitation experiment was exhibited again. The apparatus consisted of a cylindrical glass jar 41 inches high and about 10 inches in diameter. It was closed hermetically with a cap extending down the sides at least two inches. It was filled with what Keely said was pure water. On the bottom of the jar was one of the disks before described, standing on edge, also a globe covered with gold leaf about the size of an orange, with a small cylindrical projection on one side on which it rested. Keely said the globe was filled with shot. This jar stood on a small pine table upon a thick sheet of glass. In the cap of the jar Keely said there were copper and platinum strips which were responsive to certain vibrations. On the table near the jar he placed what he called a "Sympathetic Negative Transmitter," and connected this with a thumb-screw on the cap of the jar by a platinum wire. This transmitter was a large brass ball about eight inches in diameter, from one side of which protruded a straight cylindrical handle, or bar, which, by turning one way or the other, was projected into or drawn out of the ball. The movements resembled those made in operating the combination of a safe. On the outside of the ball was a small horn formed of a tube of increasing diameter, coiled with its large end outside. Also three small disks of metal into the circumference of which spines of metal of various length were inserted, forming a scale of tones when snapped. One was the diatonic scale, one harmonic, and one attuned to fifths.

Keely then placed a sensitized disk on top of the jar, and another at its base. He explained that the disks and the objects inside the jar were in sympathy with each other, and that it was essential thus to place them. Then turning the knob or handle of his transmitter a few times, as if to adjust it, he snapped the spines on the scales at different points, and soon the weights at the bottom of the jar began to quiver; the disk started slowly upward, followed by the shotted weight, and with a slow, uniform motion they rose to the surface and bumped against the cap, bobbing up and down until they came to rest. The disk,

which started first, moved faster than the globe. Keely explained that this was due to the difference in the rates of vibration of their chords of mass. This difference was 120 per minute, and he could, with care, make one ascend while the other descended or remained at the bottom. He played a few notes on a mouth-organ, disconnected the platinum wire from the jar and said the weights would remain at the top indefinitely. The jar was left while the visitors looked at other apparatus, and after a time they were found still on the top. Keely connected the transmitter and jar again by the wire, struck some chords, and the weights descended. He played a chord softly on the mouth-organ, repeating it at short intervals, and both started to rise; using the handle of the transmitter and changing the chord after they had risen three or four inches, the shotted ball dropped to the bottom while the disk continued to the top.

An interesting experiment of a different character was made in the third room. The apparatus stood in the northwest corner on a table with a glass top. It was a large ball covered with gold foil mounted upon an axis upon which it revolved stiffly and was considerably out of balance. It looked like an old timer. The two investigators stood by the apparatus while Keely went into the middle room and looked through an aperture, just large enough to show his face, across the room to the the ball. From the axis of the globe ran a thread of black silk to Keely and was attached to a zither. Keely said the ball would turn round once, twice or any number of times the visitors might name. One was suggested, and Keely struck a chord on his instrument and the ball turned over once. Three was called, and another chord resulted in its rolling over three times, and so on with other numbers, or it would roll rapidly when so indicated. It went with a wobbling motion and seemed to be rubbing on something. When it stopped it stopped suddenly. It was also noted by the visitors that the same number of turns did not necessarily require the same chord on the zither.

The great machine for navigating an air-ship also stood in this room. It had wheels not made to revolve, but only to be set to certain combinations. It was covered with resonators, sensitized disks and spiny scales, and had on the end of a large shaft

a gong, or Kladna, as Keely called it, which when struck created as much dismay as a fire-bell in the night. This machine, which weighed tons, Keely said would rise like a feather by creating about it a vibratory condition which annihilated gravity. He was understood to say that this same apparatus had been moved about the room in that very way.

After these three visits Mrs. Moore was plainly told by the two gentlemen that they had seen no evidence of any new force in any of the experiments shown by Mr. Keely. In fact some of them were readily explainable by the laws of nature already known, and no doubt, with proper facilities for investigation in addition to what the eyes alone had afforded, they would be able to explain them all.

Soon after this Mrs. Moore arranged with Professor W. Las-

REVOLVING BALL.

celles-Scott, of London, to come to Philadelphia and examine the apparatus and be instructed by Keely in the secrets of its operation. He arrived in this city in March and entered upon his investigations. Mrs Moore said to the writer that the Professor was to be allowed to handle and take apart the apparatus, which was a greater privilege than had been allowed to any prior investigator.

There was naturally great curiosity to know what opinion the English scientist would form. He was unknown to the scientific world on this side of the water, but to the writer he said he was "late consulting expert to the India Museum under Dr. Forbes Watson, and lecturer on chemistry and physics to the London Conservatoire." From this it would appear that he had some reputation in his own country, and would be entirely

competent, with the facilities afforded him, to pass a proper judgment on Keely's invention. The Professor pursued his inquiries for fully a month before he made any public expression of his views, and it was with great interest that the members of the Franklin Institute, at the monthly meeting, held April 15th, listened to his remarks.

He stated in brief, that he had commenced to get a glimmering idea of Keely's great principle, which was based upon vibrations, a subject with which the Professor declared himself thoroughly familiar, as he had devoted much attention to it, and had published some of the results of his investigations in that branch of physics. He had, he said, been quite unable for some time to understand Keely's explanations, as they were made in language too unscientific, the terms used being unintelligible, because, although the words were familiar, Keely had used them out of their generally-accepted meaning, giving them a signification known only to himself, and possibly to Mrs. Moore. The Professor stated, however, that it was his opinion that "Keely had certainly discovered a means of utilizing a force that has been suspected, but has never before been realized in any form." He could say it was neither magnetism nor electricity, either static or in the form of a current.

In saying so much the Professor stated that he told less than he knew. He promised, after he had more fully investigated the matter, to come again before the Institute and tell the result of his study into Keely's secrets. That promise was never fulfilled.

About a fortnight after the Franklin Institute meeting, Mrs. Moore sent for the writer and said that Professor Lascelles-Scott had arranged an experiment which would convince him that he was entirely wrong in his surmises as to the force used in experiments already witnessed, and named Saturday afternoon, May 2d, for a meeting at Keely's laboratory.

On that day there were present Mrs. Moore, Mr. Elliott (a friend of Mrs. Moore's), Professor W. Lascelles-Scott, E. A. Scott and Mr. Keely. It had been assumed that the writer believed that the platinum wire, connecting the sympathetic negative transmitter with the "vibrodyne" or engine, carried a current of electricity, and the Professor had arranged for a delicate test to show that

not the faintest current could be detected in the wire. The mere statement of the object of the experiment was sufficient, and Mr. Scott said he granted the conclusion at once and without experiment, as he had no thought that the wire was used as a conductor of electricity. The wire had been wound in its center, into a small coil of a dozen or more turns, and within this coil it was proposed to insert a rod of soft iron, which the Professor stated had been chemically prepared, so as to produce the best results. Keely had himself made this coil and when the Professor carelessly took the wire in his hand to explain it, Keely nervously took it from him, saying it might become broken and that he had wound it with great care. The writer, as on former visits, was not permitted to handle anything, and was repeatedly cautioned not to do so. He used his eyes, however, to the best advantage in examining the coil which it had cost Keely so much trouble to wind, to see the evidences of its being a tube, and in the flattening at certain places, the tendency to bend at an angle at others, and its general tendency to bend in the form of a polygon instead of a circle when being wound, there was no reason to doubt his former convictions that the "wire," which seems to be an inseparable adjunct to Keely's apparatus generally, was a thin platinum tube. This latest experiment only afforded additional proof of what was quite well known before.

On one of the visits with Mr. Burk, the writer picked up one end of the platinum wire which had fallen on the floor at the end of an experiment, and held it up so that Mr. Burk could see that it was a tube.

Following his general policy at all these visits, the writer did not avow his belief. A question indicating doubt or a statement of a discovery made would have prevented him from seeing other experiments where he might obtain further confirmation of his views. When Mr. Elliott, who had never before seen any of Keely's experiments, began to ask questions, which both the Professor and Keely answered, the writer asked the privilege of making some stenographic notes, which Keely had permitted on a former visit, and he occasionally asked a question himself on points not well covered by the other questions. This conversation brought out the description of the construction of the

"sympathetic negative transmitter," which forms so important a part of the whole system, and without which but few experiments are made. The Professor's description in his own words was, that "it is a hollow globe, the axis of which (a cylinder 1½ inches in diameter) is retractible within certain ranges; that is, it is drawn out or thrust into the globe by turning it like a screw. That axis carries a sensitive disk, called a kladna, which is sensitive to vibrations of every kind, and especially to those vibrations which are inaudible, beyond the voice to utter or ear to perceive. Therefore Keely is quite right when he calls it a sensitive disk. Beyond the kladna is a series of resonators, on this same central axis, and when it is screwed in or out the kladna and the series of tubular resonators (which resemble small organ pipes) go backwards and forwards, and occupy different positions in this globe, sometimes central, sometimes a little to one side and sometimes a little to the other side."

Keely said the moving of the disk inside is to get one way the attraction and the other way the repulsion. He added to the description: "There is also a sympathetic scale, formed of straight wires of different length stuck around the edge of a disk, which represents progressive chords, the same as in a piano. This scale is placed on the axis, between the kladna and the resonators, and all are fixed on the central axis. On the outside of the globe is a similar scale, which to a certain degree corresponds to the scale on the inside. There is also another smaller scale on the outside, which has two series of spines or wires. I might use three of these spines for one experiment and half a dozen at another. There is no regular interval of sound between any two of the spines; they vary one-quarter tone to one-half tone and sometimes a full tone. The larger scale has about seventy spines."

The above description by the English scientist and Keely is all that is known of the interior construction of the "sympathetic negative transmitter." The only apparent use of the axis or handle is to shift the position of the kladna, the resonators and the spines to a greater or less distance from the center of the globe by turning it backwards and forwards.

Keely then exhibited his levitation experiment, or the floating of heavy weights in a jar of water, which the writer had seen on

each of his three former visits. He noticed that the jar was a new one and had a different cap or cover from the one he had before seen. The Professor explained that, at his instance, Keely had taken a new jar and that it had been filled with distilled water. He said he was familiar with the general principle of the experiment. Two weights similar in every respect to the weights used in the old jar, were reposing on the bottom, the one, a disk-shaped flat brass box, without a cover, filled with amalgam, and

Levitation Experiment.

the other, an orange-shaped globe, said to be filled with shot. In answer to the writer, Keely said these were not the same weights which were used in the old jar; the globe, however, had the same indentations and the gold-foil with which it was covered the same spotted appearance which had been particularly noted at his former visits, and the disk seemed to be the very same, although there were no distinguishing marks by which it could be absolutely identified.

The Professor said he had carefully weighed these weights before they were put into the jar and that the flat disk weighed 68 ounces and 387 grains in air, and 58 ounces 383 grains in distilled water, a difference of 10 ounces and 4 grains, which represented the water displaced. The globular object weighed 53 ounces 384 grains in air, and 45 ounces 362 grains in distilled water, a difference of 8 ounces 22 grains. The jar appeared somewhat smaller than the old one, and was 41 inches high, and perhaps 10 inches in diameter. The cover was of glass, and was sealed on with a white cement. A space from one-half to three-quarters of an inch was left between the surface of the water and the glass cover. Inserted through the cap was a plug, with a binding screw for attaching a wire. The jar stood on a small, cheap table, with a thick, glass top. Keely placed the sympathetic negative transmitter on the same table, and connected the top of the jar with it by means of the platinum wire. On the top of the jar he placed a disk similar to the one in the jar.

When everything was ready, Keely turned the handle or axis of the sympathetic transmitter, twanged some of the wires of his scale, blew softly on a mouth-organ, and the round weight started for the top, followed a few seconds later by the disk-shaped weight. In answer to the writer, he said he could not reverse the order of their rising The tone of B natural, he said, started the first one to go up, and B flat the second one. He struck a tuning-fork for the purpose of subdividing those notes, he said, and setting a chord for their descent. Then, again turning his handle, and blowing upon his mouth-organ, the disk-shaped weight came down first at the end of about three minutes, the other remaining at the top for a time. He said he could arrest it before it reached the bottom, but failed to do so, and it struck the bottom and bounced up and down three or four times before it finally settled itself. Afterwards, he sent both to the top, and then sent the disk to the bottom, leaving the globular weight at the top, where he said he could make it stay ten years. After about three minutes, with blasts upon the mouth-organ, and turning the handle backwards and forwards, the ball was sent to the bottom, where it struck and bounced up about four inches.

The writer found by jarring the table with his knee, which he

did several times unobserved, he could make the weights bounce up 3 or 4 inches without the aid of the sympathetic negative transmitter, the mouth-organ or the "chord of mass," which was rather remarkable, when the specific gravity of the weights, as given by Professor W. Lascelles-Scott, is taken into consideration. It was an experiment in vibrations which were quite visible, though inaudible, and which produced results that did not demand for their explanation the theoretical force of "apergy."

At this point, the Professor gave as his general conclusion on this levitation experiment of Keely's, that if Keely were to take a standard barometer, a standard thermometer, and a standard electroscope, and take the condition of the air at the time of making an experiment, and would also have his scales graduated in precise tones, which they were not at present, then with the barometer reading for instance at 29.5, the thermometer at 55.5, and the electroscope at .26, with a certain response note and chord of mass, and a certain note struck upon the sensitive sympathetic transmitter, he could at all times raise the weights to the top without feeling his way as at present; and another note would as certainly send them to the bottom. This, he said, was the first time he had unbosomed himself so far; but that was his opinion, founded upon what he had seen there. Keely replied that we were just beginning to learn sound sense.

From what has already been explained, it will be at once evident that the rise and fall of the weights in the jar of water is due to their varying specific gravity. The weights sink, because they are heavier than the water, bulk for bulk; they rise because they are lighter than an equal volume of water. Keely's weights were so balanced that a slight difference in the air-pressure in the enclosed space above the water would make them rise or fall by changing their size sufficiently to make them of less or greater specific gravity. This is easily accomplished by having some portion of the weight compressible. It is a child's toy. Keely's transmitter, containing compressed air, was capable of increasing the air-pressure in the jar by turning the handle or switch to some point which would connect the jar with the reservoir of compressed air, or diminish the pressure by a change of the switch which would connect the jar with the open air.

Keely, whose eyes were always on the weights, shut off the switch as soon as the weights either rose or fell. With great skill and by letting in the air very slowly, he was sometimes able to leave one weight at the bottom, the other going to the top, or even to send one of them down after it had partly risen. It was particularly noted, however, that the one which always sunk first was the only one which he could arrest in its upward movement. Indeed, he replied to the writer's inquiry on that point, that he could not make the other go down first. He might have done so between the visits of the same investigators by changing the relative specific gravity of the weights. His explanation of his inability to do this was made in such terms of the new science that, while it sounded all right in the ear, it conveyed no meaning to the listener. It may have been stupidity on the part of the visitor. Indeed, when Keely heard of his explanation of the experiments, he said that he "considered that the Professor's testimony outweighed Mr. Scott's suspicions, and he did not think it necessary to do anything to convince him of his ignorance."

The Keely motor, or engine, is the last of the long series of Keely's inventions, of which the apparatus before referred to are only experimental studies. The word "vibrodyne" was coined by Professor W. Lascelles-Scott, as being more nearly expressive of the character of the machine than "dynamo," which Keely had used. It is supposed to embody the principles which Keely has labored so many years to establish. He says it is operated directly by "apergy," a force hitherto unknown, existing in nature and only waiting to be utilized; that it consists, like light, in the extremely rapid vibrations of the ether, or matter infinitely divisible which pervades the universe; the problem being to devise apparatus which will respond to these vibrations. The vibrodyne may be thus described:

A heavy cast-iron bed plate, supported eighteen inches above the floor by an iron slab at each end, bolted to the floor at each of the four corners by heavy iron rods, and braced from the side wall, forms the foundation for a machine which can be prevented from running by the pressure of a finger, or stopped when at full speed by grasping it with one hand.

A flat brass ring about four feet in diameter is supported on

together by the mysterious platinum wire which figures in nearly all the experiments. The outside resonators and inside disks are about two inches apart.

Concentric with and inside of this ring is the revolving wheel. Its axis is supported at each end upon large iron pillars much enlarged at the bearings of the axle. A large hub in the middle of the axle has radiating from it eight spokes, one less than the number of opposing disks on the inside of the flat ring. These spokes do not terminate in a rim, but on the end of each is a disk similar in size and character to those which project inward from the ring. There is also upon the axle near the hub a heavy iron ring about fourteen inches in diameter, which revolves with it, presumably as a balance wheel to make a steady motion. This ring had been added at some time between the last two visits, probably at the suggestion of the Professor.

On the occasion of the last visit Keely set the wheel revolving in the following manner: Taking a 10-inch sympathetic negative transmitter (the large brass ball) he placed it on a table having a glass top, on one side of the room, and connected it with the vibrodyne by a platinum wire, attaching one wire to the binding post of the transmitter, and the other to the binding post projecting from a resonator on the top of the vibrodyne. Then, snapping some of the wires on the scale of the transmitter and turning the handle backwards and forwards, the wheel commenced to revolve, slowly at first and with gradually increasing speed, until the revolutions were about 180 per minute.

The Professor asked: "Am I right that you can stop the wheel by withdrawing that kladna?" (The kladna on the axis would be withdrawn by turning the axis or handle of the transmitter in one direction.)

Keely said "yes," and appeared to turn the handle about twenty times, and, snapping one of the wires, which he said was note B, the wheel slowed down, and finally stopped.

He started the wheel again as before, and said: "As the machine now revolves the subdivision is 42,800 to the second. That is disintegrating vibration. I could disintegrate quartz with that vibration and powder it into dust." He did not offer to powder any quartz in that way, however.

Keely suggested that he could stop the wheel in several ways, two of which he illustrated. He pulled the wire out of the binding post of the transmitter, and it stopped as before. Again starting it, he stopped it by pulling out a plug in a hole in the binding post on the machine, the hole being a continuation of the hole into which the wire was thrust on the other side. This left the transmitter attached to the machine, and gave the writer an unexpected opportunity to further confirm his belief that the so-called platinum wire was a small platinum tube. He had noted on his first visit that the method of attaching the wire to a binding post was peculiar. The post was in form like a T and was hollow. There was no screw to hold the wire in place, but the ends of the wire terminated in plugs which were pushed into the end of the hollow arms of the T. On this occasion he observed that not only the horizontal arms of the T, but also the perpendicular leg, were hollow, leaving a passage down into and through the resonator, the flat ring, the sensitized disk on the inside of the ring and the binding post upon the disk, to which was attached the platinum wire before described, which encircled the interior side of the flat ring.

On the present occasion the writer took his seat next to the revolving wheel, not following Keely's suggestion to take another position. When Keely pulled out the plug from one arm of the T, leaving the wire sticking in the other arm, the other end of the wire still being connected with the sympathetic negative transmitter, he moved his face close to the hole left by the plug, which had been pulled out, and distinctly felt a blast of air from the tube (or "wire").

To make certain that the air current did not come from the revolving spokes, he kept his face in the same position until the wheel had stopped, and still felt the full force of the blast of air from the tube.

Here then was a confirmation of his belief that the wire was a tube carrying compressed air, the reservoir of which was the 10-inch globe of the "sympathetic negative transmitter." It was evident, however, that a sufficient amount of power to run the wheel for any length of time, or to run it at all, could not be stored in a globe of that size. He did not believe that it was so run,

but that the air pressure performed the office either of an automatic switch-closer or automatic pole-changer on an electric circuit. This belief was to some extent confirmed by an oracular remark of the Professor to Mr. Elliott, to whom he said: "The wire does not supply the power, but it unlocks the power which runs the wheel." The writer at once said to him: "Professor, you have exactly expressed my opinion."

Now, as to the electrical features of the vibrodyne. Assuming that the compressed air flowing through the tube performed the office only of a starter, that it produced the conditions in the machine necessary to allow a more potent force to act, what force was applied by its action? The construction of the machine points directly to electricity acting through magnetism. If Professor Lascelles-Scott took the apparatus apart, he must have discovered the mode of its operation. The unnecessarily heavy parts of the machine afforded every opportunity for the concealment of the small wires necessary for the power developed, or the bolts which run down through the floor to hold down the iron foundation could have served as conductors. It was an easy matter to bring a current to electro-magnets concealed in the nine interior disks, and no great amount of ingenuity would be required to construct a switch, operated upon both by the compressed air and magnetism, which would cut the magnet into or out of circuit at the proper time to attract the armature on the end of each revolving spoke. Had there been nine spokes as well as nine opposing disks, the wheel would have got on a dead center, and could not always have been started; but with only eight spokes there were always some in a position to receive a magnetic pull before the magnets were cut out of circuit by the opposing disks being exactly opposite each other. The evidence of design here is sufficiently strong to warrant the conclusion that the wheel is operated by electro-magnets. Apergy would not have required this arrangement.

Keely said to the writer that the hub of the wheel was loose on the axle, and that when running at a high rate of speed he could knock out the axle and the wheel would continue to turn in space. Such an exhibition would have been interesting, and would have convinced the writer that the force was not mag-

netism, which was the chief object of the exhibition, but he did not do it, nor did he offer to do many other things which he spoke of as being easy, and which would have astonished the investigators.

It was decided on the occasion of the second visit by both of the investigators, that magnetism had nothing to do with the jar experiment, as the motion of the bodies was uniform, which it would not have been if actuated by a magnet. The theory of a tube made everything plain, and Mr. Burk has had constructed a jar which he used in explaining the phenomenon before the Spring Garden Institute last winter, using an air pump for the transmitter.

Within half an hour after the close of the last visit, Mrs. Moore called on the writer at his residence to learn of him his conclusions. He explained to her fully the use of the platinum tube, and advised her to have the experiment repeated and convince herself of the fact by taking a pair of pincers and pressing the sides of the tube together, when the revolving wheel would stop; or to cut for herself a section from the middle of the supposed wire while the machine was in action and examine it. She consented to have the experiment repeated in her presence and permit the writer to make the cut, but he told her she could never persuade Keely to repeat the experiment for such a purpose. She was more than half convinced, but afterwards saw the Professor and asked him to see the writer on this subject.

The English scientist came the same evening, and for four hours the events of the day were discussed. He gave an account of his investigations in vibratory physics, and particularly in reference to the simultaneous explosions of two or more powder mills situated at considerable distances apart, the result of vibration; and considered the phenomenon analogous to some of Keely's experiments. Criticisms by the writer on Keely's work, and inquiries as to the discoveries the Professor had made, led up to the Professor's part in the preparation of the second jar, the one used in the experiments of that day. He told of his care in procuring the distilled water, and in obtaining the exact weight of the globe and disk, which were placed in the jar. When asked if he personally placed the

weights in the jar or saw them placed there, and saw the jar sealed, he admitted that he did not, but that Keely did this himself. He was asked, "Do I understand that you, a professional expert in physics, would trust to the man you are investigating to do these things, and then have the conscience to make a report to your employer of the result of such an investigation?" He mildly admitted that it would have been better to be present.

Likewise when the platinum tube was mentioned, he stoutly denied that it was a tube, saying that he had several samples of the platinum wire and knew it to be solid. He had taken samples of almost everything he had investigated. When asked where he got his samples and whether he had cut them from wires he had seen used in the experiments, he said he had taken them from a reel of the wire.

The Professor agreed with the writer that the best way to prove or disprove the use of the tube would be to have the experiments repeated and allow the writer to show the character of the wire employed. The writer told the Professor that Keely would never make such an exhibition under those conditions. The Professor visited Keely the next day, Sunday, and on the following day informed Mrs. Moore that Keely had declined point blank to repeat the experiments, "just as I was told he would do," he added. He suggested to her the absolute necessity of Keely doing this in his own best interest. Keely could not, however, be induced to do so. The Professor left the city at once, and under the circumstances, as he explained, thought it best not to appear a second time before the Franklin Institute.

The explanation here given is not, of course, a complete explanation of all that is to be seen in Keely's laboratory. Indeed it would take more than four visits to look over, which is all that was permitted, the apparatus which was accumulated in a quarter of a century. It is enough, however, to show that nothing was shown in motion which required a force to move it which is not already known. The manner of the use of such forces, as used in these experiments, would probably, in the minds of most people, throw a doubt upon the probability of Keely's knowledge of any more mysterious force.

DISCUSSION.*

Prof. H. W. Spangler stated that his investigations had fully convinced him that all the experiments and results exhibited by Mr. Keely could be explained under recognized laws and principles, and that as yet there was no evidence produced that a new form of force had been discovered. Some years ago he had an opportunity to examine closely the so called sensitized bar and noted that it was made of several pieces which had been neatly joined in the manner indicated by Mr. Scott. Dr. Leidy's statements had been somewhat erroneously reported. The true statement was that if Mr. Keely's claims are well-founded, he is one of the greatest discoverers the world has ever seen.

Mr. Chas. B. Collier (non-member) stated that he had been for many years associated with Mr. Keely's work. He dissented from many of the opinions of Mr. Scott, asserting among others that the so-called wire was not a tube and that compressed air was not and could not be used with the apparatus. He referred to visits made to the Keely laboratory by both recognized and alleged expert physicists, and asserted that Mr. Lancaster Thomas and himself were familiar with Mr. Keely's method. He declared that he was willing to perform the experiments in the presence of the Club, but Mr. Keely's consent could never be obtained to such a procedure. He exhibited drawings purporting to represent the mechanical details of the various forms of apparatus. Prof. Rowland, of the Johns Hopkins University, saw the levitation experiment and asserted that the wire was a tube and asked that it should be cut across to decide the matter, but Mr. Keely refused.

Brief remarks were also made by Messrs. Hering, Schumann and Marburg.

Mr. Scott, in closing the discussion, spoke as follows:

Mr. Scott.—I cannot answer all Mr. Collier has said, as a large proportion of his remarks were devoted to something that a Mr. Brown published in the *New York Herald* and to much correspondence based upon that publication, with which I am entirely unfamiliar. I am gratified, however, that the two points on which I laid most stress in my paper have been unexpectedly confirmed by the discussion. The first is in regard to the alleged molecular vibration of the bar. I knew nothing until to-night of Professor Spangler's discovery that Keely's sensitized bar was made exactly like the one we had constructed at the Spring Garden Institute in imitation of it.

* Owing to a misunderstanding, the discussion was not fully reported. It is, therefore, given in abstract and in a form somewhat different from that usually followed.

The other point, that the suppositious wire is a platinum tube, has been confirmed by Mr. Collier himself. I had not before heard that so eminent a physicist as Professor Rowland had visited Keely's laboratory and had come to the same conclusion, although he could not demonstrate it by facts as I have done. His experience, however, was identical with mine in that Keely could not be forced to show whether it was a wire or tube by permitting it to be cut. Mr. Collier has contented himself with denying it is a tube, notwithstanding the facts I have adduced proving it to be one. I suspected it on the first of my four visits, and confirmed it at each subsequent visit.

I omitted to mention in my paper an interesting experiment in which this tube played an important part. Picking up one of the resonators, or bundles of short pipes, which was capped over at each end, he attached it to a sympathetic negative transmitter by the platinum tube. On the top of it he placed an ordinary compass, which pointed naturally to the north. Operating the transmitter and snapping chords on the scales the compass needle commenced to revolve rapidly, and finally stopped, pointing south-east. It was also made to stop at other points of the compass. This experiment was tried on each of the four visits, on one of which the compass used was one belonging to the Spring Garden Institute.

On the last visit, Keely, to show that there was no connection made with the compass, placed one of the sensitized disks on top of the resonator, thereby raising the compass an inch or more. The effect was at once apparent. The compass needle, which had before been running with its point much depressed, straightened itself up, the point being much less depressed, just as it would have done had it been raised further from a controlling magnet. Had there been a magnet concealed in the resonator, whirled around by a little current of compressed air, the result would have been just what was witnessed. I do not say that Keely did it that way, but all the facts pointed to it.

XVII.

REPLACEMENT OF THE OLD METAL-SPAN OF THE PENNSYLVANIA RAILROAD BRIDGE OVER THE SCHUYLKILL RIVER AT PHILADELPHIA, OCTOBER 17, 1897.

By JOSEPH T. RICHARDS, Member A. S. C. E.

Read December 4, 1897.

THE replacing of the metal-span of the bridge carrying the New York Division of the Pennsylvania Railroad over the Schuylkill River near Girard Avenue, Philadelphia, has been commented on quite generally, from the fact that the old span of 236 feet 3 inches in length, was moved out, and the new span moved 27 feet to take its place, in precisely 2 minutes and 28 seconds, the time between trains passing over the old span before moving, and the new span placed in position, being 13 minutes.

I have been requested by a number of my friends to give sufficient description to show the actual preparations and the conditions under which this transfer of bridges was made. It is probably due to the Pennsylvania Railroad Company's organization, as well as to the engineering profession of America, that a statement of facts be officially made, more particularly since the publications abroad, especially the English technical journals, have discredited the statements given by our American newspapers, so far as to term it an *incredible feat.* In order to make this plain, it is with regret that I take the time and space to reprint a sample of the derisive language published by the *Industries and Iron,* of London, under date of November 19, 1897:

"TWO REMARKABLE ENGINEERING FEATS.

"Look on this picture, and on that. Feat No. 1.—The widening of the Great Northern Railway from King's Cross to Huntingdon is rapidly proceeding, and on Sunday last the Company's engineers performed a remarkable feat in reconstruction. The old iron bridge south of Hatfield, and over which run four lines of rails, was temporarily closed, and with every necessary appliance in readiness, the old bridge was removed and

replaced by a new iron girder bridge in about fifty minutes. This is creditable and credible. Feat No. 2.—A remarkable engineering feat was recently accomplished in America. The Pennsylvania Railway Company removed the old bridge over the Schuylkill River, and simultaneously replaced it with a heavier steel structure, 242 feet long and 25 feet wide. The removal was completed in 2 minutes and 28 seconds, and a train crossed the new bridge within 12 minutes from the starting of the work. This would be creditable if credible. We think the veracity machine of the author of the second statement must be slightly out of gear. So are the reflective powers of the editors of the various British journals in which it has been reproduced with appreciative comments."

This may be passed, however, as it evidently is almost an *incredible feat* for our English friends, yet it is but little more than an ordinary matter for President Thomson's organization of the Pennsylvania Railroad.

The details of the new span will not be entered into here, as my particular subject is the replacement of the old span, but the dimensions and weight are pertinent, and it may be well to say, that the new span is a double track deck Pratt truss, 235 feet 7 inches long, c. to c. of end pins, consisting of 11 panels of 21 feet 5 inches each, 25 feet 9 inches in depth, the trusses being spaced 19 feet apart, c. to c. The weight of metal in the new span is 570 tons. The metal in the old span weighed 404 tons. The total weight of both spans, including floor systems and track as moved, was about 1250 tons.

That part of the New York Division on which this bridge is located is known as the Connecting Railway. The old bridge was built during the construction of this road in 1867. The entire viaduct spans both the east and west drives of Fairmount Park, as well as the Schuylkill River, and crosses over Girard Avenue at the intersection of Thirty-fourth Street and the Park entrance. The approaches consist of a series of stone arches, six at the east, and nine at the west approach, with a metal span over the water. The total length of the viaduct, including arches and metal span, is 972 feet, end to end. The old metal span was known as a Linville truss, being a double intersection or Whipple type. The height of the bridge is 68 feet 3 inches from base of rail to the water line. The water has a depth of 23

to 40 feet, being within the slack water of Fairmount dam. The bottom of the dam has a strata of 6 to 12 feet of mud and clay, under which is a firm bed of hard gravel and sand. The center line of the railroad runs approximately east and west, crossing the river at about right angles.

In renewing bridges of this kind, one of two methods may be adopted. One is to trestle up the old bridge, and interweave the new one piece by piece, through the old structure under the tracks, while trains are in operation. This is a slow process, but not always objectionable, and sometimes adopted in our railroad work. The other method is the one practised at this time, of building the new span, complete, alongside of the old one, and moving it to place and the old one out between trains. The first method has the advantage of making absolutely sure that no delay will occur to trains, and requires less engineering skill than the second, which may be considered to have an element of uncertainty about getting the new one in place within a given time between trains. The latter method, however, has the advantage of giving a better opportunity to assemble and erect the new span, riveting up every part without being disturbed by passing trains, and without having a load placed on any part of the bridge until it is completed and ready for service, all of which generally finishes the bridge in better condition than could otherwise be done, and is the reason for adopting it here.

The new bridge was placed under contract May 24th, 1897; the preliminary work and erection followed in due time. The falseworks consisted of square sawed timber driven to hard bottom, forming a pile-timber platform which surrounded the abutment piers and extended north and south a sufficient distance to be used to support the new span during its erection on the south side, and to receive the old span when rolled out of place on the north side. The top or floor dimensions of this platform was 42 feet in width by 108 feet in length. It also provided working space for the bridge carpenters, stationary boilers, engines, pulling ropes, etc. The preparations for moving, that is, preparing and placing the bed rails and rollers under both the old and new spans, erecting the blocks and ropes, furnishing and placing the stationary engines with power sufficient to haul the two bridges,

all went on during the erection of the new span, so that by the time the latter was completed, everything was in readiness for the interchange of the two spans. Shortly before the completion of these preparations, the old span (which had been carried clear of the rollers) was jacked up with hydraulic jacks, and the rollers placed under the ends. It is not well to do this too long in advance of the time set for moving, as the weight long standing on the rollers might result in flattening some of them, or forcing them down into the rails on which they rest, and consequently give trouble in starting the bridge. The foundation or bed for the rollers was composed of six ordinary 85-pound track rails, placed on substantial timber framing reaching across the bridge seats, and extending up and down stream. These rails were laid in their normal position (heads up). Upon them the nest of continuous rollers was placed, each roller being $2\frac{7}{16}$ inches diameter by 36 inches long, placed 6 inches apart, c. to c.; 136 of these rollers were used under each end of the spans. They were connected together by side straps to prevent them from sluing or clustering when rolling. On top of the rollers a second set of six 85-pound track rails were placed in their normal position, and upon which the pedestals of the old and new spans were allowed to rest. The six rails forming each bed-plate were rigidly spliced and bolted together, uniting them into one. The power to move the spans was supplied by an upright boiler and engine, having four drums, placed at each end of the span, on the platform of the temporary faleworks, together with two auxiliary engines on barges down near the water level. These engines had a combined capacity of about 100 H. P., or 50 H. P. at each end of the bridge. Four sets of four-sheave blocks, or eight sets of rope, were used in connection with these engines, making 32 lines of 2-inch rope at each end, the ninth rope running to the drums of the engines. Four similar blocks were connected to the end posts of the bridges, which were strengthened by temporary rods around the struts between at the base, to which the blocks and rope were attached, one set of blocks and ropes going past the old span to reach and connect with the end posts of the new span on the south side. The anchorage to which the eight blocks were attached consisted of heavily braced clusters of timbers on the extreme north end

A NEST OF ROLLERS.

of the falseworks, which were well braced against the masonry piers. Two emergency 60-ton jacks, one at each end of the span, were put at the extreme south end of the falseworks, placed with strong abutting timbers, to be used in case the bridge for any reason did not start promptly; these, however, were not brought into use, as the bridge started without them. As a further precaution against a sudden or too rapid movement after starting, or against the possibility of hauling the bridge past its proper resting place, a check block and tackle was rigged on the south side at each end, and a rope wound around a snubbing post with a skillful carpenter in attendance. This emergency rope, however, was not brought into use, as it was not found necessary. The distance the two spans were moved was 27 feet. One of the greatest precautions to be taken, was to insure each end of the spans to move alike, as there was a clearance of but four inches between the masonry and the top chords of the bridge, and it can readily be understood that should one end roll in advance of the other, the bridges would not travel in the proper line, and would result in striking the masonry, thus bringing the operation to a standstill, a position from which it would take considerable time to disengage. To provide against this, a very simple device was arranged by fastening two ropes permanently to the masonry, one at each end, and extending out along the top chord to the center of the span, passing around a wheel and descending to a short distance below the bottom chord, with two large weights suspended from the end of each rope, side by side, with tops and bottoms even. Should one end move faster than the other, one weight would be seen to rise above the other, and the fast end would necessarily be slowed down, and the slow end advanced until the weights were again seen to be on a level. This proved to be a very good method and assisted much in the rapid progress made. As an auxiliary device, a long board divided into feet and inches was nailed across the face of the abutment walls with an index attached to the bridge which travelled with the moving spans along the face of the board, thus pointing out the feet and inches moved at each end.

The joining of the track on top of the bridge, was a matter requiring accurate measurement. The rails laid for the double

track on the new span 27 feet away, were to fit precisely the gap left by the rails moved away with the old span. Four joints at each end, or eight in all, were to be made, and an error of but a small fraction of an inch in the measurements of the track, or by reason of the bridge moving out of its prescribed line, would cause a loss of time, necessitating the cutting or shifting of the rails, which could not be afforded when working under such close a margin. To guard against this possible delay, switch points were on hand to joint up to one rail and extend along the other; they were not used, however, as the rails jointed perfectly, and the regular splice bars and bolts were put on before trains passed over.

After all preparations were completed, the day set for moving the bridge was Sunday, October 17, 1897; during the afternoon there are the fewest number of trains passing over this busy part of the main line. To make it plain, I will give the schedule taken from the time-table at this point, as follows:

Train	No. 811,	west-bound,	2.20	P.M.,	Chestnut Hill Local.
"	No. 50,	east-bound,	2.36	"	Express through from the South.
"	No. 932,	west-bound,	2.38	"	Philadelphia and Atlantic City Express.
"	No. 810,	east-bound,	2.53	"	Chestnut Hill Local.
"	No. 926,	east-bound,	3.41	"	Chestnut Hill Local.
"	No. 36,	east-bound,	4.05	"	Richmond and New York Express.
"	No. 927,	west-bound,	4.07	"	Chestnut Hill Local.

From this the greatest time between trains during an entire day is found to be 48 minutes, being between two east-bound Chestnut Hill trains, one passing at 2.53, the next following at 3.41 (the west-bound track being clear during the same time); consequently this time was selected for the work.

At the time of moving, the 2.53 P.M. train from Broad Street Station passed over at precisely at 2.57; the track was broken at 2.58, the bridge started to move at 2.59. Both spans moved together, and the new span was in position at 3.01 and 28 seconds; actual time of moving, 2 minutes and 28 seconds. At 3.08 the track east-bound was connected ready for trains; at 3.10 the west-bound track was connected ready for trains. At 3.10 a locomotive, No. 1064, drawing private car No. 229, passed over the east-bound track. At 3.17 a regular freight train passed over

[Proceedings Engineers' Club of Philadelphia, Vol. XIV, No. 4, January, 1898.]

The New Span Ready for Moving.

[Proceedings Engineers' Club of Philadelphia, Vol. XIV, No. 4, January, 1898.

Combination Derrick and Pile-Driver.

west-bound track. Time between the last train east at 2.57 and the special train passing over the same track at 3.10, was 13 minutes.

The above figures given are sufficient indication of the nicety and precision which this transfer was made, and no accident to cause either a delay or an injury to any of the workmen in connection with the operation occurred to detract from the successfully planned and executed work.

After the transfer, as may be understood, the old span occupied a position to the north, or up-stream side of the railroad, its ends being supported by the false works, the new span assumed the responsibility of carrying the busy traffic, which the old one had borne so well for the past thirty years.

DISCUSSION.

WALTER L. WEBB.—I wish to ask about the rollers and supports under the bridge. They must have been taken out later, but the bridge must have been on the rollers when the first train passed over it. I presume that the bridge was not dropped; something was put in to replace the rollers. Were the rollers turned?

MR. RICHARDS.—It was on rollers and the old bridge was on rollers for two days before it was moved. The new bridge was raised a few inches; this was all that was required, because there were bed-plates to go under the iron bridge-seat. Immediately under the rollers there was another iron bed-plate to rest on the masonry. The rollers were rolled, not turned.

JAMES CHRISTIE.—This feat was a remarkable one considering the rapidity of the movement, and the extent and magnitude of the structure. Work of this kind has been done before, with work of less importance. I recall a case in Newark, N. J., about 25 years ago. A highway bridge crosses the canal askew, one end of the trusses resting on a girder spanning the canal. The exigencies of the case required that the truss should be assembled at a distant point, and slid transversely to its destination. This was very quickly done—the trusses being handled separately.

NOTES AND COMMUNICATIONS.

Celebration of the Twentieth Anniversary of the Organization of the Club.

THE Twentieth Anniversary of the organization of the Club was celebrated by a dinner at the Manufacturers' Club, on Friday, December 17, 1897. The President of the Club, Mr. Joseph T. Richards, presided, and Mr. John Birkinbine acted as Toast-master.

Messrs. Eglin, Gwilliam and Leffmann constituted the Special Committee of Arrangements.

MENU

"I think one business doth command us all."

ROCKAWAY OYSTERS

GREEN TURTLE SOUP

TERRAPIN ENCASED

ROAST TENDERLOIN WITH MUSHROOMS
BRUSSELS SPROUTS POTATO CROQUETTES

ROMAN PUNCH

" I may justly say with the hook-nosed fellow
of Rome: 'I came, saw and overcame.' "

ROAST QUAIL, STUFFED
CELERY

LETTUCE, MAYONNAISE

HARLEQUIN ICE CREAM CAKES

CHEESE

COFFEE

" Serenely calm, the Epicure would say
Fate cannot harm me, I have dined to-day."

TOASTS

"THE ENGINEERING PROFESSION," .... Henry W. Spangler

" Let him show
His skill in the construction."

"MUNICIPAL ENGINEERING," .... George S. Webster

"The axis of the earth sticks out visibly through the
center of each and every town or city."

"MECHANICAL ENGINEERING,"................................John H. Converse

"Then may I set the world on wheels."

"MINING ENGINEERING,"..Henry M. Chance

"In the clefts of the valleys must they dwell,
In the holes of the earth and of the rocks."

"ELECTRICAL ENGINEERING,"..E. A. Scott

"Canst thou send forth ligthnings, that they may come,
And say unto thee: Here we are?"

"THE PAST, PRESENT AND FUTURE OF THE CLUB,"...........Wilfred Lewis

"Zögernd kommt die Zukunft hergezogen
Pfeilschnell ist das Jetzt entflogen
Ewig still steht die Vergangenheit."

About eighty-five members and guests were present.

ANNUAL REPORT OF THE BOARD OF DIRECTORS.

FOR THE FISCAL YEAR 1897.

JANUARY 15, 1898.

TO THE ENGINEERS' CLUB OF PHILADELPHIA.

In compliance with the requirements of the By-Laws, the Board of Directors offers the following report of the affairs of the Club for the year ending December 31, 1897:

During the year eighteen regular meetings of the Club were held, at which the maximum attendance was ninety-six, and the average about seventy.

Twelve meetings of the Board were held, at all of which a quorum was present.

The business of the Board has been much facilitated by the rules and regulations adopted last year, which have been continued in force this year. Additional rules defining more explicity the functions of the various committees have been adopted with much advantage.

The annual reports of the standing Committees to the Board are herewith presented:

MEMBERSHIP COMMITTEE.

During the year twenty-two Active, six Associate and six Junior members have been elected, fourteen Active and one Associate member resigned, thirteen Active and two Associate members have been dropped, and three Active and one Associate member died. One death occurring in 1896 was reported in 1897. These changes have resulted in a loss of one in the total membership of the Club.

The record of death is as follows:

Graham Spencer, Active Member, died November 21, 1896.
(Not previously reported.)
George B. Roberts, Active Member, died January 30, 1897.
Isaac S. Cassin, Active Member, died March 7, 1897.
Rudolph Boericke, Active Member, died December 25, 1897.
Charles G. Hildreth, Associate Member, died July 9, 1897.

The membership of the Club on December 31, 1897, was as follows:

Class.	Resident.	Non-Resident.	Total.
Honorary		1	1
Active	279	114	393
Associate	15	2	17
Junior	6	0	6
	300	117	417

INFORMATION COMMITTEE.

The Committee, fully aware of the importance of obtaining suitable papers for presentation upon the diversified subjects relating to the various branches of the profession, has made all efforts in this direction, by soliciting contributions from mem-

bers and non-members, upon subjects with which they are conversant. While much interesting material is promised, the authors have not been able to fix definite dates, hence the Committee was unable to present in advance a program of papers with dates of presentation.

The Committee would urge upon the members of the Club the desirability of furnishing papers, no matter how brief, provided they contain points of general interest to the profession, and would also call the attention of the members to the rule allotting two meetings during the year for Topical Discussions. It would greatly aid the Committee if members would submit suggestions as to subjects for discussion.

The papers during the year 1897 were uniformly interesting, and were as follows:

JANUARY 2.—Memorial of Amasa Ely.

JANUARY 16.—Annual Report of the Board of Directors. Address of Retiring President, A. Falkenau. Japanese Railroads. By H. Iwasaki and K. Nagatani.

FEBRUARY 6.—Steam Boilers as the Inspector finds them. By George B. Hartley.

FEBRUARY 20.—Steel as viewed by the Engineer. By P. Kreuzpointner. The Future Habitation of the Club. By Joseph T. Richards.

MARCH 6.—Memorial of George B. Roberts. The Sewage-Disposal Plant at Altoona, Pa. By Harvey Linton.

MARCH 20.—The Construction of the Queen Lane Reservoir, Philadelphia. By John C. Trautwine, Jr.

APRIL 3.—Experiments for Determining the Velocity of the Flow of Water in Sewers. By Charles Jacobsen. Construction of the Queen Lane Reservoir, Philadelphia. By Edwin F. Smith.

APRIL 17.—The Installation of the Niagara Falls Power Co. By Charles F. Scott.

MAY 1.—The Superstructure of the Delaware River Bridge at Bridesburg, Philadelphia. By Paul L. Wolfel.

MAY 15.—Topical Discussion.—Modern High Office-Buildings.

JUNE 5.—The Bertrand-Thiel Modification of the Open-Hearth Process. By J. S. Robeson. Rainfall and Stream-Flow Observations in Eastern Pennsylvania. By John E. Codman.

SEPTEMBER 18.—The Engineering Chemistry of Clay. By Henry Leffmann.

OCTOBER 2.—The Delaware River Bridge at Easton, Pennsylvania. By J. M. Porter.

OCTOBER 16.—Breakwater Construction on the American Coast. By L. Y. Schermerhorn.

NOVEMBER 6.—Some Features of Stone-Road Construction. By Benjamin Franklin.

NOVEMBER 20.—The Mass-Curve in Earthwork Computations. By Walter L. Webb.

DECEMBER 4.—Moving the Pennsylvania Railroad Bridge over the Schuylkill River. By Joseph T. Richards.

DECEMBER 18.—Topical Discussion.—A Better House for the Engineers' Club of Philadelphia.

PUBLICATION COMMITTEE.

When the present Publication Committee assumed charge, the publication of the PROCEEDINGS was being carried out under a contract with a publishing firm, but after the issue of the April number, the contract was dissolved and the subsequent

numbers have been published solely under the control of the Club, the firm merely acting as advertising agents. The change of contract interfered with the prompt issue of the midsummer number of the PROCEEDINGS.

The Committee hoped to begin this year, the publication of the PROCEEDINGS monthly, but the publishers were unwilling to take the responsibility, and the Committee has not felt warranted in undertaking this plan under present arrangements; nevertheless it is thought that the issuance of the PROCEEDINGS ten months in the year would be of great benefit to the Club, and no appreciable additional net expense. To make such a system successful, a stringent enforcement of the rules in regard to furnishing the papers read before the Club, and copy for illustrations, would be required to secure promptness in the appearance of each number, without which the plan would have no advantages.

The usual number of papers has been published during the year, together with notes and communications, book-reviews and the reports of the meetings of the Club and Board of Directors.

During the latter part of the year, the Committee has inaugurated the plan of having papers set up prior to the reading and a limited number of galley-proofs prepared to be distributed to such persons as the author of the paper may designate, with an invitation to present a written or oral discussion thereon. In cases in which the plan has been carried out it has been quite satisfactory, and it is believed that it adds much to the thoroughness of the discussions.

LIBRARY COMMITTEE.

The Library Committee begs to report its maintenance of the subscription and exchange lists, thus ensuring to the Club Library a continuance of the leading technical journals. An unusually large number of works on engineering and kindred subjects has been donated during the year. No action has been taken on the recommendation that a Librarian be appointed. While the Committee believes that the Library should be placed on a basis commensurate with its value to the Club, the uncertainty as to the future habitation of the Club calls for a postponement of the expenditure of money at this time other than is necessary to preserve the material we now have and to prepare the many pamphlets for binding. For the same reason the Committee refrains from making recommendations.

HOUSE COMMITTEE.

Keeping in view the possible early vacation of the present Club House, the House Committee has confined the purchase of required new furnishings to such articles as can be readily used elsewhere.

The office of the Club has been moved from the second to the third floor, and the former office has been remodelled into a card and smoking room.

For facilitating the business of the Club, a roll-top desk for the office, a stand for the electric lantern, and a larger ballot-box have been purchased. A telephone, for the general use of the Club, has also been installed.

Permission for the use of the Club rooms has been granted to the American Boiler Makers' Association and to the Committee of the American Society of Civil Engineers, on Uniformity of Cement Tests. The House Committee would remind the members that the use of the Club rooms for meetings of kindred organizations has been authorized by the Board of Directors, and application therefor should be made to this Committee.

FINANCE COMMITTEE.

	Expenditures for 1896.	Estimate for 1897.	Expenditures for 1897.	Estimate for 1898.
Salaries	$1,190 50	$1,200 00	$1,221 50	$1,250 00
Proceedings	500 45*	....	651 28*	200 00†
House	1,397 98	1,400 00	1,445 65	1,500 00
Luncheons	677 50	800 00	696 00	700 00
Notices	540 89	600 00	329 66	400 00
Secretary's Office	202 00	250 00	176 13	250 00
Treasurer's Office	81 30	100 00	67 00	80 00
Library	70 20	250 00	37 94	50 00
Information Committee	63 99	150 00	44 64	100 00
Sinking Fund	....	....	....	....
Miscellaneous	41 25	100 00	....	....
House Improvements	396 43	....	156 59	250 00
Liabilities of 1895 paid	764 17	....	....	....
Total Expenditures & Estimates.	$5,926 66	$4,850 00	$4,826 39	$4,780 00

* Total expenditure. † Estimated net cost.

JOSEPH T. RICHARDS, *President.*
L. F. RONDINELLA, *Secretary.*

ANNUAL REPORT OF THE TREASURER FOR 1897.

Receipts.

Dues and Initiation Fees:		
1895	$8 20	
1896	300 00	
1897	4,572 50	
1898	145 00	
		$5,025 70
Advertisements		$179 00
Proceedings		79 03
Interest on Deposits		25 31
Reprints		31 50
Lantern Slides		1 00
Keys		2 00
Total Income		$5,343 54
Cash Balance, Dec. 31, 1896		113 36
		$5,456 90

Expenditures.

Salaries:		
Secretary	$240 00	
Treasurer	60 00	
Clerks	621 50	
Janitor	300 00	
		$1,221 50
House:		
Rent	$1,100 00	
Coal	148 00	
Gas	68 50	
Ice	18 25	
Repairs, Supplies, etc.	88 40	
Insurance	22 50	
		$1,445 65
House Improvements:		
Furniture and Fixtures		$156 59
Secretary's Office:		
Stamped envelopes, stationery, postage, and supplies		$173 13
Proceedings		593 78
Notices		329 66
Treasurer's Office		67 00
Information Committee		44 64
Library		37 94
Luncheons		696 00
Affidavit of Tellers		3 00
Reprints		57 50
Total Disbursements		$4,826 39
Cash Balance, Dec. 31, 1897		630 51
		$5,456 90

Respectfully submitted,

GEO. T. GWILLIAM, *Treasurer.*

Examined, compared with vouchers, bank and check-books, and found correct,

JAMES CHRISTIE,
H. W. SPANGLER, *Auditors.*
W. P. DALLETT,

ABSTRACT OF MINUTES OF THE CLUB.

BUSINESS MEETING, December 4, 1897.—The President, Joseph T. Richards, in the chair. Seventy-three members and visitors present.

The Tellers presented a supplementary report, stating that Mr. P. McManus had been duly elected an associate member at the election held November 7th, but through a mistake his name had not been included in the list reported on that date.

The following nominations for officers for 1898 were made:

Nominee.	Proposer.	Seconder.
	PRESIDENT.	
Edgar Marburg.	A. Falkenau.	John Birkinbine.
L. Y. Schermerhorn.	James Christie.	F. Schumann.
	VICE-PRESIDENT.	
Wm. C. L. Eglin.	Henry Leffmann.	Carl Hering.
	SECRETARY.	
L. F. Rondinella.	John Birkinbine.	James Christie.
	TREASURER.	
George T. Gwilliam.	Minford Levis.	Wm. C. L. Eglin.
	DIRECTORS.	
W. Copeland Furber.	Henry Leffmann.	Geo. S. Webster.
Edwin F. Smith.	J. C. Trautwine, Jr.	John E. Codman.
L. Y. Schermerhorn.	J. C. Trautwine, Jr.	John E. Codman.
R. L. Humphrey.	Geo. T. Gwilliam.	F. Bloch.
	Harrison Souder.	Geo. B. Taylor.
C. H. Ott.	Geo. S. Webster.	J. C. Trautwine, Jr.

Mr. Joseph T. Richards read a paper, entitled "Replacement of the Old Span of the P. R. R. Bridge over the Schuylkill River."

The subject was discussed by Messrs. Christie, Marburg, and others.

Dr. Leffmann showed some lantern slides, illustrating the ancient aqueduct at Lyons, France.

Mr. J. E. Codman showed some lantern slides of picturesque scenery in Maine.

BUSINESS MEETING, December 18, 1897.—The First Vice-President, Mr. Carl Hering, in the chair. Sixty-five members and visitors present.

The Tellers reported the election of Messrs. J. F. Hasskarl, Theo. Spencer, and A. B. Stowell to active membership, and M. F. Wilfong to associate membership.

A topical discussion on the subject "A Better House for the Engineers' Club of Philadelphia" was opened by the presentation of the report of the Special Committee on New Building. The following resolution was adopted:

That the report of the Committee be referred to the Board of Directors, with instructions to ascertain what amount of subscription of second mortgage bonds could

be obtained, and what proportion of the resident membership would agree to a raising of the dues to twenty dollars per year in the event of the purchase of a new club-house, to investigate the availability and cost of buildings, and to consider the question of renting a club-house in another location.

REGULAR MEETING, January 1, 1898.—The President, Joseph T. Richards, in the chair. Five members present.

The death of Mr. Rudolph Boericke, on December 25, 1897, was announced.

Routine business only was transacted.

SPECIAL MEETING, Januay 8, 1898.—The President, Joseph T. Richards, in the chair. One hundred and six members and visitors present.

The Tellers reported the election of Messrs. J. F. Baker, C. M. Mills, E. D. Thompson, C. H. Umstead, and C. I. Young to active membership.

Mr. E. A. Scott read a paper entitled "The Keely Motor." The subject was discussed by Messrs. Spangler, Marburg, Schumann, and C. B. Collier (non-member).

BUSINESS MEETING, January 15, 1898.—The President, Joseph T. Richards, in the chair. Seventy-five members and visitors present.

Mr. Joseph T. Richards read the address as Retiring President.

The annual report of the Board of Directors was presented and discussed.

The Tellers announced the following as the result of the election of officers:

President—L. Y. Schermerhorn.
Vice-President—Wm. C. L. Eglin.
Secretary—L. F. Rondinella.
Treasurer—Geo. T. Gwilliam.
Directors—R. L. Humphrey, C. H. Ott, and E. F. Smith.

ABSTRACT OF THE MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, December 18, 1897.—Present: The President, the Second Vice-President, Directors Livingston, Schermerhorn, Eglin, Hartley and Schumann, the Secretary and the Treasurer.

The Treasurer's Report showed:

Balance on hand November 1st	$455 80	
Receipts in November	402 70	
		$858 50
Expenditures in November		105 75
Balance November 30, 1897		$752 75

Resignations of active membership were presented and accepted from Messrs. Edgar Piercy, John S. Mucklé and J. Franklin Stevens.

SPECIAL MEETING, January 3, 1898.—Present: The Vice-Presidents; Directors Eglin, Schumann, Livingston, Hartley, and Schermerhorn; the Secretary and the Treasurer.

The Annual Report of the Board of Directors was submitted by Dr. Leffmann, Chairman of the Special Committee appointed to prepare it. It was considered by paragraphs, and after slight changes in phraseology it was adopted for presentation to the Club at its Annual Meeting.

Upon motion, duly seconded and carried, the Treasurer was ordered to bring legal action for the collection of all delinquent dues.

Resignations of Active Membership were presented and accepted from Messrs. Thomas J. Carlile, Wm. H. Adey, G. D. Chenoweth and Louis S. Wright, and of Associate Membership from Mr. S. E. Moore.

REGULAR MEETING, January 15, 1898.—Present: The President, the Vice-Presidents, Directors Schermerhorn, Livingston, Ott, Schumann, Eglin, and Hartley, the Secretary and the Treasurer.

Routine business was transacted.

ORGANIZATION MEETING, January 22, 1898.—Present: The President, the Vice-Presidents, Directors Ott, Schumann, Hartley and Smith, the Secretary and the Treasurer. On motion Mr. H. C. Lüders was elected a director for the unexpired term of Mr. Wm. C. L. Eglin, elected Vice-President.

The President announced the Standing Committees for 1898. (See official list.)

The Treasurer stated that he would probably be absent from the city for several months and requested that some arrangements be made for conducting the business of his office during that period. On motion it was decided that the Treasurer should be authorized to execute a power of attorney to Dr. Minford Lewis to sign checks under the authorization of the Finance Committee.

CONTRIBUTIONS TO THE LIBRARY.

FROM G. W. CREIGHTON.

Rail Joints.
Comparative Experiments upon the Strength of Rail Joints.

FROM AMERICAN SOCIETY OF MINING ENGINEERS.

Improvements in Mining and Metallurgical Appliances during the Last Decade;—Spilsbury.
The Iron Ore Supply;—Birkinbine.
Explorations on the Mesah Range;—Longyear.
The Technology of Cement Plaster;—Wilkinson.
Investigations of Water Supply;—Newell.
The Marquette Range—Its Discovery, Development and Resources;—Jopling.
Mining Methods on the Mesah Range;—Bailey.
Notes on Six Months' Working of Dover Furnace, Canal Dover, Ohio.
Biographical Notice of Peter Ritter von Turner;—Raymond.
The Electrolytic Assay of Lead on Rolled and Drawn Brass.
The Calorific Value of American Coals.
A New Form for Ingot-Mould for Casting Brass or Bronze Ingots, with Remarks on the General Form of Ingots;—Sperry.
The Genesis of Certain Auriferous Lodes;—Dow.

FROM LEHIGH UNIVERSITY.

The Probability of Hit When the Probable Error in Aim is Known: With a Comparison of the Probabilities of Hit by the Methods of Independent and Parallel Fire from Mortar Batteries.
Past and Present Tendencies in Engineering Education.

FROM C. W. RAYMOND.

Improvement of Rivers and Harbors in Southern New Jersey; of Delaware River and Bay, and of Waters Tributary thereto, New Jersey, Pennsylvania and Delaware.

FROM AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Transaction, Volume XVIII, 1897.

FROM SMITHSONIAN INSTITUTION.

Annual Report, 1895.
Report, National Museum, 1890

FROM UNITED STATES GEOLOGICAL SURVEY.

Water Supply and Irrigation Paper
No. 5, Irrigation Practice on the Great Plains;—Cowgill.
No. 4, A Reconnoisance in S. E. Washington;—Russell.
No. 6, Underground Waters of S. W. Kansas;—Haworth.
No. 7, Seepage Water of Northern Utah;—Fortier.
No. 8, Windmills for Irrigation;—Murphy.
No. 9, Irrigation near Greeley, Col.;—Boyd.
No. 11, River Heights, 1896;—Davis.

FROM UNIVERSITY OF WISCONSIN.

A Comparative Test of Steam Injectors;—Trautman.

FROM PURDUE SOCIETY OF CIVIL ENGINEERING.

Proceedings, 1897.

FROM ENGINEERING ASSOCIATION OF SOUTH WALES.

Proceedings, Volume IX, 1893-94.

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